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US Army Corps of Engineers

REPAIR, EVALUATION, MAINTENANCE, AND REHABILITATION RESEARCH PROGRAM

TECHNICAL REPORT REMR-OM-4

A RATING SYSTEM FOR THE CONCRETE IN NAVIGATION LOCK MONOLITHS

by

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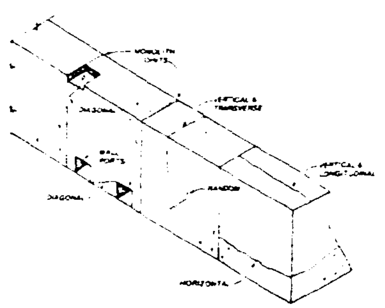

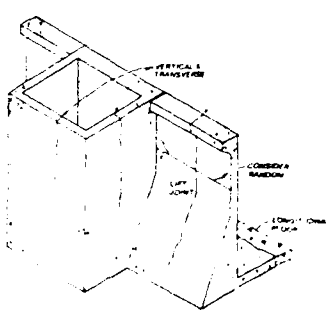

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GT	Geotechnical	EI	Environmental Impacts
HY	Hydraulics	OM	Operations Management
CO	Coastal		

COVER PHOTOS

TOP Simplified crack representations of a gravity structure

BOTTOM Simplified crack representation of a U-frame structure

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19 ABSTRACT (Continue on reverse if necessary and identify by block number)

The purpose of this report is to describe a proposed system for determining a condition index (CI) that numerically rates the condition of the concrete in a lock monolith on a scale of 0 to 100 by evaluating each concrete deficiency. The rating system described herein allows the CI to be determined by the use of a visual investigation with limited equipment. The rating is related primarily to structural integrity and secondarily to serviceability.

The CI procedure was developed by assigning specific deduct values to defects which include the following distress categories: alignment, cracking (checking, D-cracking, pattern, horizontal, vertical and transverse, vertical and longitudinal, diagonal, random, and longitudinal floor), volume loss (abrasion, cavitation, honeycomb, pop-outs, scaling, spalling, and disintegration), steel deterioration (corrosion stains, reinforcing, prestressing,
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16. SUPPLEMENTARY NOTATION (Continued).

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19. ABSTRACT (Continued).

and armor), and leakage and deposits. The deduct values are substracted from 100 to establish the CI. Primary deduct values were determined with the intent of obtaining a CI of zero when deterioration of a concrete monolith caused the safety of that monolith to become critical. Nominal deduct values were assigned for defects in serviceability.

Deduct values for distress categories that tend to result in loss of concrete from the structure (volume), and thus effective weight and cross section, were assigned by making approximations concerning safety and assuming (a) all sections were cracked so that no tension or cohesion existed at the section and (b) the total force tending to produce sliding or total moment tending to produce overturning was constant.

The CI should be determined on all gate monoliths, on at least one of each of the remaining types of monoliths, and on the more distressed monoliths. It is recommended that a minimum of 10 percent of the monoliths be rated.

PREFACE

The study reported herein was authorized by Headquarters, US Army Corps of Engineers (HQUSACE), as part of the Operations Management Problem Area of the Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Research Program. The work was performed under Civil Works Research Work Unit 32280, "Development of Uniform Evaluation Procedures and Condition Index for Deteriorated Structures and Equipment," for which Dr. Anthony M. Kao is Principal Investigator. Mr. James E. Crews is the REMR Technical Monitor for this study.

Mr. Jesse A. Pfeiffer, Jr., is the REMR Coordinator at the Directorate of Research and Development, HQUSACE. Mr. Crews and Dr. Tony C. Liu serve as the REMR Overview Committee. Dr. Kao is the Problem Area Leader for the Operations Management problem area.

This study was sponsored by the US Army Engineer Waterways Experiment Station (WES) and conducted by Mr. Rupert Bullock, Engineering Consultant, Knoxville, TN, under Contract No. DACA39-87-M-0744 to WES. The study was performed under the general supervision of Mr. Bryant Mather, Chief, Structures Laboratory (SL), WES, and Mr. Kenneth Saucier, Chief, Concrete Technology Division (CTD), SL, and under the direct supervision of Mr. William F. McCleese, CTD. Program Manager for REMR is Mr. McCleese. Final editing for publication was done by Mmes. Gilda Miller and Chris Habeeb, Editor and Editorial Assistant, respectively, Information Products Division, Information Technology Laboratory, WES.

COL Dwayne G. Lee, EN, is the Commander and Director of WES. Dr. Robert W. Whalin is Technical Director.

CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
degrees (angle)	0.01745329	radians
feet	0.3048	metres
gallons (US liquid)	3.785412	litres
inches	25.4	millimetres

A RATING SYSTEM FOR THE CONCRETE IN NAVIGATION LOCK MONOLITHS

PART I: INTRODUCTION

Background

1. The US Army Corps of Engineers operates approximately 270 navigation lock chambers constructed of plain or reinforced concrete. Many of these structures require, or will require, significant repairs to ensure safe and efficient operations. A quantitative rating system for the condition of concrete in a navigation lock would make possible the determination of which lock, which monoliths within a lock, and which deficiency within a monolith most merit repair. Successive ratings with time would provide a measure of the rate of deterioration. The methodology for such a system has previously been developed and used for pavement.*

Purpose

2. The purpose of this report is to describe a proposed system for determining a condition index (CI) value that numerically rates the condition of the concrete in a lock monolith on a scale of 0 to 100 (Figure 1) by evaluating each concrete deficiency. Figure 2 groups the condition index values into three zones that are related to engineering and management actions.

Scope

3. The CI prescribed herein applies only to the concrete in the navigation lock. Other factors that are not rated herein, such as foundation deterioration, may also affect the safety of a lock monolith. Other elements such as gates and machinery require a separate rating system. Under no circumstances should the CI of the concrete in the lock be taken as the overall CI of the lock.

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* M. Y. Shahin, and S. D. Kohn. 1981 (Oct). "Pavement Maintenance Management for Roads and Parking Lots," Technical Report M-294, US Army Construction Engineering Research Laboratory, Champaign, IL.

Value		Condition Description
85 to 100	EXCELLENT:	No noticeable defects. Some aging or wear may be visible.
70 to 84	VERY GOOD:	Only minor deterioration or defects are evident.
55 to 69	GOOD:	Some deterioration or defects are evident, but function is not significantly affected.
40 to 54	FAIR:	Moderate deterioration. Function is still adequate.
25 to 39	POOR:	Serious deterioration in at least some portions of structure. Function is inadequate.
10 to 24	VERY POOR:	Extensive deterioration. Barely functional.
1 to 9	FAILED:	No longer functions. General failure or failure of a major component.

Figure 1. Condition index scale

ZONE	CI RANGE	ACTION
1	70 - 100	IMMEDIATE ACTION IS NOT REQUIRED.
2	40 - 69	ECONOMIC ANALYSIS OF REPAIR ALTERNATIVES IS RECOMMENDED TO DETERMINE APPROPRIATE MAINTENANCE ACTION.
3	0 - 39	DETAILED EVALUATION IS REQUIRED TO DETERMINE THE NEED FOR REPAIR, REHABILITATION, OR RECONSTRUCTION.

Figure 2. General interpretation of the condition index scale

4. The rating system described herein allows the CI to be determined by the use of a visual investigation with limited equipment. The rating is related primarily to structural integrity and secondarily to serviceability. An expanded investigation including engineering evaluations should be made when the CI is 40 or below.

PART II: DEVELOPMENT

General

5. The CI procedure was developed by assigning specific deduct values to defects defined in Appendix A, "Guide for Making a Condition Survey of Concrete in Service," ACI 201.1R-68.* A "very fine" crack category that is less than 0.01 in.** wide was added. The deduct values are substracted from 100 to establish the CI. Primary deduct values were determined with the intent of obtaining a CI of zero when deterioration of a concrete monolith caused the safety of that monolith to become critical. Nominal deduct values were assigned for defects in serviceability. The system is designed to be independent of the inspector conducting the inspection. However, field experience with different trained inspectors rating the same lock monoliths has shown that a variation of ±10 in the CI for a monolith can be expected. The variation can be expected to be greater if the inspectors have not received formal training on the use of this system.

Volume Loss

6. Deduct values for distress categories that tend to result in loss of concrete from the structure (volume), and thus effective weight and cross section, were assigned by making approximations concerning safety and assuming: (a) all sections were cracked so that no tension or cohesion existed at the section and (b) the total force tending to produce sliding or total moment tending to produce overturning was constant. Although the first assumption is conservative, the second may not be. Changes in ground-water level, uplift pressures, or shear strength of backfill may result in some increase in force or moment. However, as previously stated, a detailed investigation of such factors and an engineering evaluation should be made when the CI is determined to be 40 or below. This practice will prevent excessive deterioration in

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* American Concrete Institute Committee 201. 1980. "Guide for Making a Condition Survey of Concrete in Service," ACI 201.1R-68, <u>ACI Manual of Concrete Practice</u>, Part 1, Detroit, MI.

** A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 3.

safety factor before remedial action is taken. Safety against both sliding and overturning was considered. The percentage of cross section in compression was determined to be the critical consideration. If a criterion of maintaining 75 percent of the undeteriorated cross section in compression is adopted and it is assumed that the section was originally designed with the resultant force at the kern boundary, then a 12-percent reduction in cross-section depth and weight on that cross section as a result of deterioration is the limit. A deduct value of 60 was set for a depth reduction of 12 percent on 100 percent of wall width, and all other deduct values were determined linearly (Figure 3).

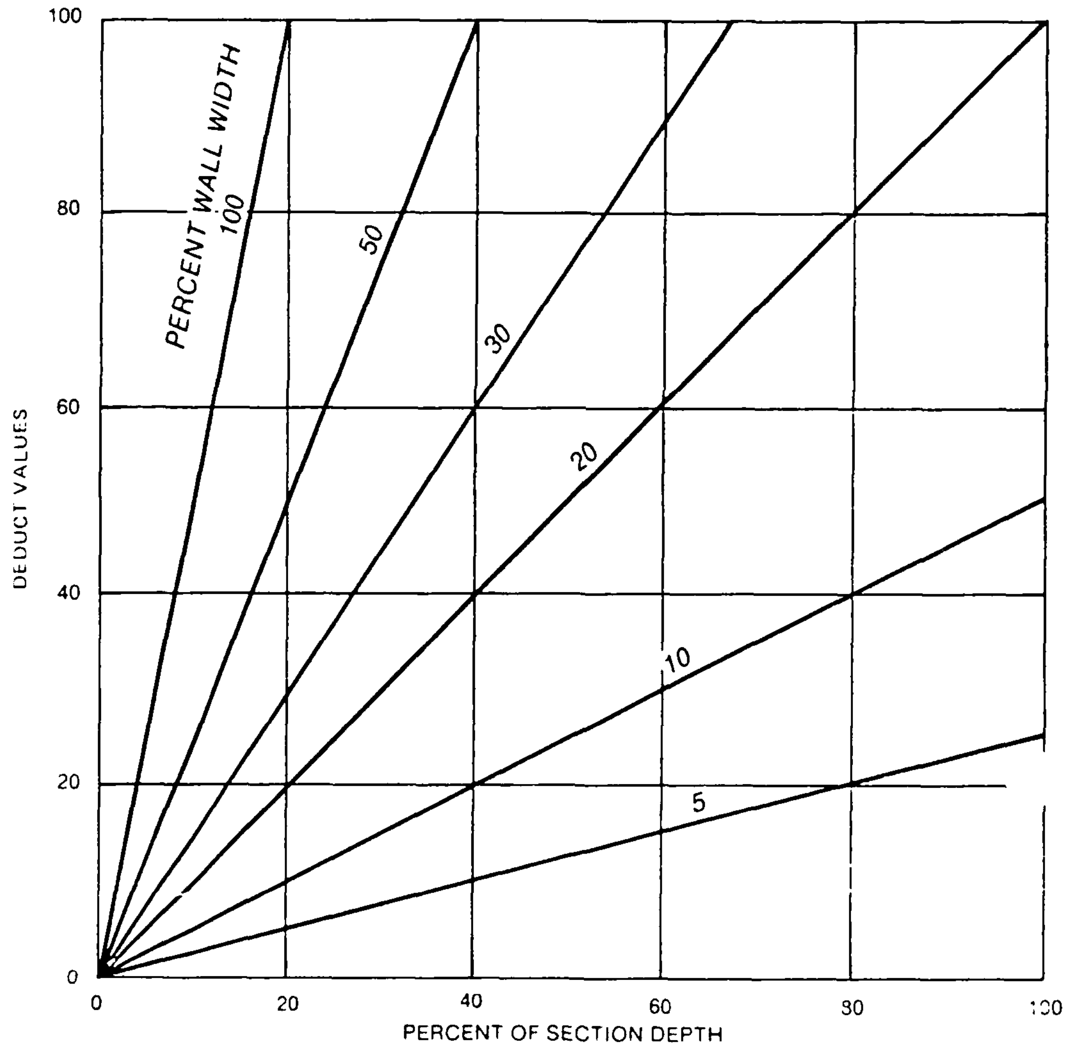


Figure 3. Volume loss deduct values

Cracking

7. Since calculation of shear transfer across cracks in a monolith subjected to bending is impractical in the present state of the art, all deduct values for cracks were set by judgment, recognizing that shear transfer would decrease as cracks widen.

PART III: METHODOLOGY

Procedure

8. The CI is determined by visual inspection and use of lock monolith field inspection and CI calculation forms (Figures 4 and 5). The lock monolith field inspection form (Figure 4) provides space for inspection details and accumulates data for input to an Engineered Management System currently being developed at the Construction Engineering Research Laboratory, Champaign, IL. This computer program will calculate the CI using deduct values discussed in the following sections and track distress data for the concrete in lockwall monoliths. The accumulation of such data affords managers a quantitative means of comparing the condition of concrete in one structure to the next. In time, this accumulation of data will provide curves yielding rates of concrete deterioration in lockwalls. In its current design, the module accepts and stores inspection data, computes deduct values and condition indices, and generates related reports. Among the report forms available are the Lock Monolith Field Inspection Form and the Lock Monolith Condition Index Calculation Form (Figure 5). Other options within the module allow the viewing and editing of inspection data, the calculation of a composite condition index for each wall of the structure, a simple Life Cycle Cost Analysis routine for use in planning maintenance strategies, and a text dialogue of concrete lockwall Maintenance and Repair Alternatives currently employed in the Corps today. The lock monolith CI calculation form lists many of the deduct values provided for each distress category described in the following section and provides a hand-calculation method for the CI. Inspection results may generally be entered on the CI calculation form during the field inspection by circling appropriate values. However, if desired, data may be collected in the field on the inspection form or other forms and the CI calculated later in the office. Construction or as-built drawings of the lock are necessary to determine such factors as monolith numbers and dimensions, depth of anchorages, and connections of monoliths by shear keys. If repairs that modify action have been made, drawings of the repairs are necessary to determine the extent of the repair and the exact location of posttension members. Equipment to clean areas and remove debris from cracks and to estimate crack widths is required. A number of other actions may be desirable such as: (a) using

LOCK MONOLITH FIELD INSPECTION FORM

Lock:__________ Monolith#:_____ L M R

Date:______ Inspector:__________ Gate Block? YES NO

Location Codes L-Land Wall M-Intermediate Wall R-River Wall LS-Land Side Face RS-River Side Face D-Deck C-Conduit F-Floor							
CRACKING							
24-Horizontal 25-Vertical&Transverse 26-Vertical&Longitudinal 27-Diagonal 28-Random 29-Longitudinal Floor							
1	Crack Category: Width: (in.)	LS	RS	D	C	F	
Remarks:							
2	Crack Category: Width: (in.)	LS	RS	D	C	F	
Remarks:							
3	Crack Category: Width: (in.)	LS	RS	D	C	F	
Remarks:							
4	Crack Category: Width: (in.)	LS	RS	D	C	F	
Remarks:							
VOLUME LOSS TYPE CRACKING / DETERIORATION							
21-Checking 22-D-Cracking 23-Pattern 31-Abrasion 32-Cavitation 33-Honeycomb 34-Pop-Outs 35-Scaling 36-Spalling 37-Disintegration							
1	Distress Category:	LS	RS	D	C	F	
Distress: width ___ depth ___ height ___ elevs. ___ Section: width ___ depth ___ (at elevation of distress) Remarks:							
2	Distress Category:	LS	RS	D	C	F	
Distress: width ___ depth ___ height ___ elevs. ___ Section: width ___ depth ___ (at elevation of distress) Remarks:							
3	Distress Category:	LS	RS	D	C	F	
Distress: width ___ depth ___ height ___ elevs. ___ Section: width ___ depth ___ (at elevation of distress) Remarks:							

a. Front

Monolith#:______

Location Codes LS-Land Side Face RS-River Side Face D-Deck C-Conduit F-Floor			
STEEL			
42-Reinforcing (exposed) O-Over 50% U-Under 50% Exposed at Section 43-Prestress (any exposure or indicated corrosion)			
42 43	LS RS D C F	O U	Remarks:
42 43	LS RS D C F	O U	
42 43	LS RS D C F	O U	
OTHER			
36-Spalled Joint 41-Corrosion Stain 44-Damaged Armor LIT-Light HVY-Heavy			
36 41 44	LS RS	LIT HVY	Remarks:
36 41 44	LS RS	LIT HVY	
36 41 44	LS RS	LIT HVY	
LEAKAGE & DEPOSITS			
51-Leakage 52-Deposits LIT-Light MOD-Moderate HVY-Heavy Moderate Leakage ≤ 10 gpm Moderate Deposit ≤ ½ inch thick			
51 52	LS RS C	LIT MOD HVY	Remarks:
51 52	LS RS C	LIT MOD HVY	
51 52	LS RS C	LIT MOD HVY	
Sketches or Comments -			
*-REMARKS: In all instances describe distress locations as completely as possible. Use the the monolith's deck, faces or joints as datums. When applicable, as in volume loss, distress width and depth may be expressed as percentages of section width or depth at given elevation. For volume loss in decks, indicate the percentage of the deck area that is affected.			

b. Back

Figure 4. Lock monolith field investigation form

LOCK MONOLITH CONDITION INDEX CALCULATION FORM

Lock: ______________________________ Monolith#: __________

Date: __________ Inspector: ______________ Gate Block? yes no

Alignment Problems?: ______________________________

DISTRESS CATEGORIES:

DISTRESS CATEGORIES	DIVISION A: All Blocks				DIVISION B: Gate Block			
	Deduct Values				Additional Deducts			
CRACKING	<=.01"	<=.04"	<=.08"	>.08	<=.01"	<=.04'	<=.08"	>.08
24 Horizontal	10	20	30	40	5	10	15	20
25 Vert & Transverse	10	20	30	40	-	10	20	30
26 Vert & Longitudinal	10	30	50	70	-	-	-	-
27 Diagonal	20	40	60	80	-	-	-	-
28 Random	10	20	40	60	-	-	-	-
29 Longit Floor	10	20	30	40	5	10	15	20

VOLUMETRIC CRACKING	%Width	%Depth	Deduct
21 Checking	100	10	50
22 D-Cracking	100	6	30
23 Pattern	100	2	10
	50	10	25
VOLUME LOSS	50	6	15
31 Abrasion	50	2	5
33 Honeycomb	20	10	10
34 Pop-outs	20	6	6
35 Scaling	20	2	2
36 Spalling	Other:		
37 Disintegration	%Width	%Depth	Deduct
Deduct = (%W)*(%D)/20	_____	_____	_____

Division B — Additional Deduct

The additional deduct value for volume loss type distress in gate blocks is equal to the deduct value computed in Division A.

Enter Deduct:_____

Enter MAX Div. B:_____

STEEL	Any Area	> 50% Area
42 Reinforcing (exposed)	30	60
43 Prestress (corrosion)	60	

CONDUITS	<= 3"	<= 6"	> 6"
31 Abrasion	10	20	30
32 Cavitation	20	40	60

Enter MAX Div. A:_____

DIVISION D: Decks

Categ	<25% Area	>25%
	5	10
	5	10
	5	10

Enter SUM Div. D:_____

DIVISION C

OTHER	Deduct Values Light		Heavy
36 Spalled Joint	5		10
41 Corrosion Stains	5		10
44 Damaged Armor	5		10
LEAKAGE & DEPOSITS	Light	Moderate	Heavy
51 Leakage	5	10	20
52 Deposits	5	10	20

Sum Div C:_____<20 MAX

COMPUTE DEDUCT VALUE:

1) Max Div. A = _____
2) Max Div. B = _____
3) Sum Div. C = _____
4) Sum Div. D = _____

TOTAL DEDUCT = _____

C. I. RATING = _____

Figure 5. Lock monolith CI calculation form

divers, (b) drilling cores and using borehole cameras, (c) installing instruments to monitor crack-width variation, (d) using soniscope surveys, and (e) making dye tests. Additional details are given by Stowe and Thornton.* Although all monoliths should be visually inspected, it may not be necessary to determine the CI of all monoliths. The CI should be determined on all gate monoliths, at least one of each remaining type of monolith, and on the more distressed monoliths. It is recommended that a minimum of 10 percent of the monoliths be rated. The space after distress categories 24 through 29 in Figure 5 may be used to indicate the number of cracks or crack location. Only the widest crack of each category results in a circled deduct value. The next blank space needs only a check mark to indicate the distress categories (21 through 37) resulting in the volume loss producing the critical deduct value. All distress categories are to be recorded in division A, unless specifically called for in the other divisions. Division B applies only to gate monoliths and includes additional deduct values for gate monoliths specifically called for under distress category discussions. Gate monoliths have additional deduct values since they are acted upon by moments and shears in two directions. Division C includes distress not directly attributable to structural integrity, and division D is for distress on decks that affects or tends to affect serviceability. Only the maximum values from divisions A and B are used in determining the CI of the monolith. The sums of deduct values in divisions C and D, subject to a maximum of 20 in division C, are used. Values obtained from each division are then added to obtain a total deduct value; however, a deduct value sum above 100 is not to be used. The resulting total deduct value is subtracted from 100 to establish the CI for the monolith. If repairs are being considered, deduct values for the distress categories to be repaired can be eliminated and a new CI projected for the monolith. Examples of completed inspection forms are included in Appendix B.

Distress Categories and Deduct Values

9. Distress categories considered herein are listed in Table 1. Each

* R. L. Stowe and H. T. Thornton, Jr. 1984 (Sep). "Engineering Condition Survey of Concrete in Service," Technical Report REMR-CS-1, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Table 1

Distress Categories

Alignment		
Cracking		
	21	Checking
	22	D-cracking
	23	Pattern
	24	Horizontal
	25	Vertical and transverse
	26	Vertical and longitudinal
	27	Diagonal
	28	Random
	29	Longitudinal floor
Volume loss		
	31	Abrasion
	32	Cavitation
	33	Honeycomb
	34	Pop-outs
	35	Scaling
	36	Spalling
	37	Disintegration
Steel deterioration		
	41	Corrosion stains
	42	Reinforcing
	43	Prestressing
	44	Armor
Leakage and deposits		
	51	Leakage
	52	Deposits

category is discussed, including guidance on how to determine deduct values. Appendix A reproduces the Appendix from ACI 201.1R-68* and contains photographs illustrating types of concrete defects. An inspector should be familiar with this guide before performing an inspection to determine the CI.

Alignment

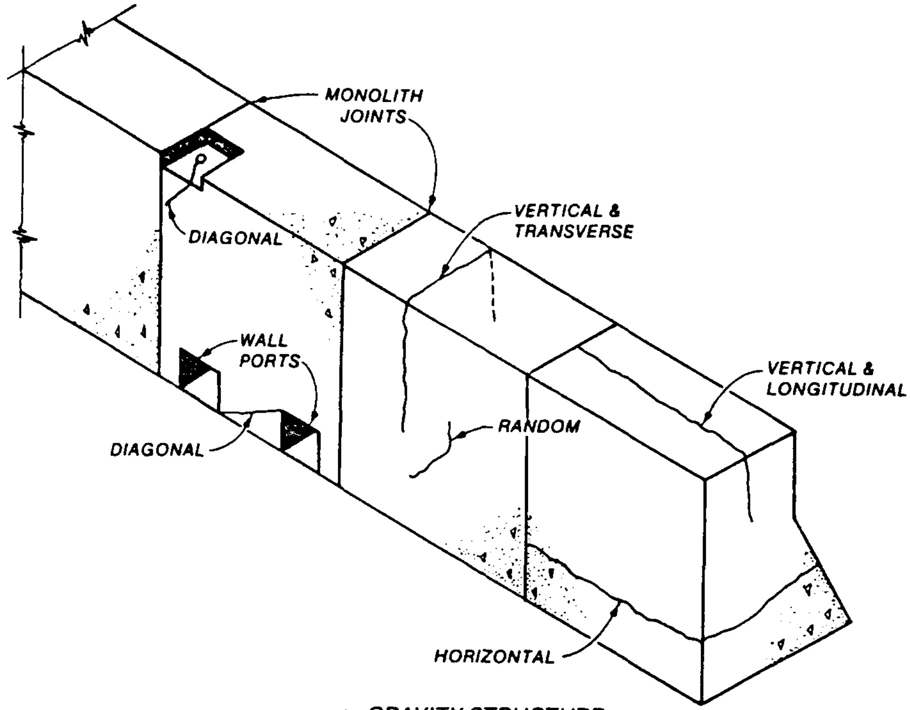
10. Alignment problems, misalignment or distortion, may result from such factors as construction procedures, load deflection, foundation movement, and concrete growth. Alignment problems do not have deduct values herein, but

* Op. cit., page 8.

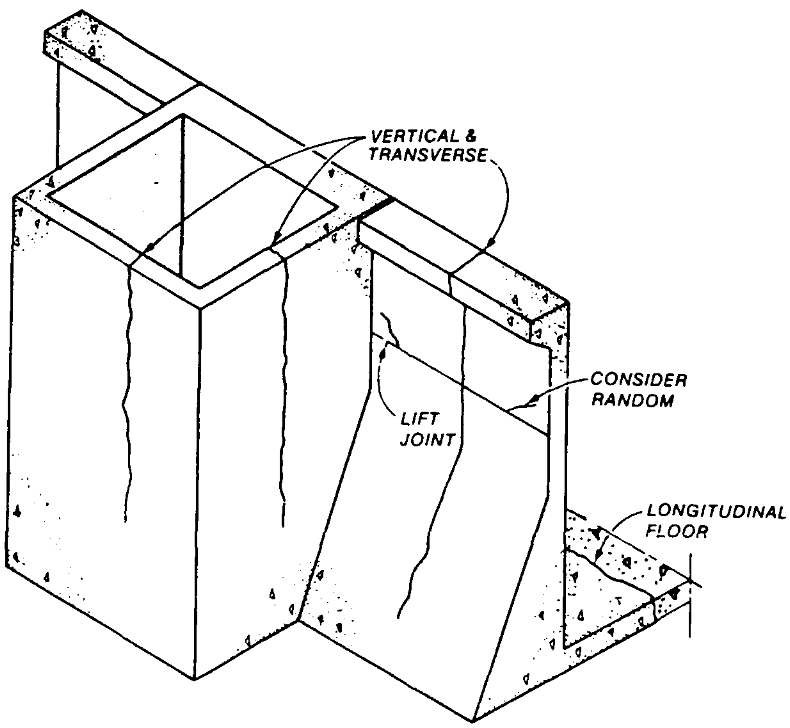
other effects that may result from the same causes may have. Any misalignment should be examined for a pattern that would indicate a cause. Is there a deflection pattern which would result from normal or abnormal loads? Is a monolith (or monoliths) displaced uniformly, horizontally, or vertically, or does the displacement indicate a rotation? Is there a variation in joint or crack opening? If a foundation problem is indicated, a foundation investigation should be initiated.

Cracking

11. A number of crack categories are provided. The first three, checking (21), D-cracking (22), and pattern cracking (23), are generally shallow surface effects that tend to result in loss of concrete. Deduct values are selected based on estimates of depth and extent, similar to volume loss deterioration (31 through 37), rather than on crack width. Where surface defects occur on opposite sides of a monolith at similar elevations, deduct values based on the estimated depth and width of each surface defect are determined and the deduct values are then added together. Widths and depths other than those already listed on Figure 5 must be written in with deduct values read from Figure 3. These types of deterioration generally do not develop to a significant depth on backfilled sides. Repairs to these categories generally require concrete removal and replacement. Repairs are effective and eliminate deduct values as long as the repair does not deteriorate or debond. The other categories of cracking, horizontal (24), vertical and transverse (25), vertical and longitudinal (26), diagonal (27), random (28), and longitudinal floor (29), have deduct values dependent on crack width. A crack width should be determined or estimated where it is widest. Two or more cracks from base restraint generally join to form one wide crack at some distance above the base. Crack categories are shown in Figure 6. Some cracks do not easily fit into a specific category. As an example, a crack that is generally horizontal may slope upward to intersect a sloping river face at an approximate right angle. Such a crack would be evaluated as a horizontal crack. Crack widths should be estimated where raveling has not enlarged the crack. Repairs to these types of cracks are generally made by grouting and stitching and are effective as long the grout does not crack or debond or otherwise show distress. If a crack is stitched without grouting, it will probably be necessary to do continuous monitoring of the crack width to determine whether the repair is fully effective. Any relative displacement along a crack of one part with respect to the part on the other side of the crack indicates a structural failure, and the deduct value



a. GRAVITY STRUCTURE



b. U-FRAME STRUCTURE

Figure 6. Simplified crack representations

is 100 points, even though redistribution of loads may have prevented collapse. Deduct values listed with each category allow for no relative displacement along the crack.

Checking (category 21)

12. Checking cracks are relatively shallow surface cracks at closely spaced but irregular intervals. Deduct values for monolith walls are determined from Figure 3. For decks, 5 points are deducted for no more than 25 percent of deck area affected and 10 points for more than 25 percent.

D-cracking (category 22)

13. D-cracks form progressively on a concrete surface as a series of fine cracks at close intervals; they form randomly but with parallel edges, joints, and major cracks. Exudations frequently form along the cracks. It is usually advisable to core concrete exhibiting severe D-cracking to determine the depth of deterioration and for examination by a petrographer to determine cause. Deduct values for walls are determined from Figure 3. For decks, values for checking (category 21) are used. Surface effects on decks are to be lumped into one area. For D-cracks on the faces of a gate monolith, two-direction bending may be accounted for by establishing division B deduct values using the depths in division A as width in division B and the widths in A as the depths in B.

Pattern cracking (category 23)

14. Pattern cracking results from a relative volume change of interior and exterior concrete. Pattern cracking together with distortion generally indicates a volume increase such as occurs from alkali-aggregate reaction. The effect is generally relatively shallow, less than 1 ft. Extensive pattern cracking makes coring advisable to determine depth and cause. Pattern cracking may progress to disintegration usually with the effects of cycles of freezing and thawing added. Deduct values are determined from Figure 3. For decks, values for checking (category 21) are used. For gate monoliths, appropriate deduct values should be established in division B as in D-cracking (category 22).

Horizontal cracking (category 24)

15. Horizontal cracks may initiate by thermal or other volume changes, and they may be at lift joints or may go to culvert or gallery openings. Deduct values are assigned as follows:

Crack Widths, in.	Deduct Values
Very fine ≤0.01	10
Fine >0.01, ≤0.04	20
Medium >0.04, ≤0.08	30
Wide >0.08	40

For gate monoliths, the division B deduct value is to be one half the above division A value.

Vertical and transverse cracking (category 25)

16. Such cracks may initiate by thermal or other volume changes and may go to machinery openings or anchorages.

Crack Widths, in.	Deduct Values
Very fine ≤0.01	10
Fine >0.01, ≤0.04	20
Medium >0.04, ≤0.08	30
Wide >0.08	40

For gate monoliths, the division B value is to be the difference between the above value in division A and the deduct values for vertical and longitudinal cracking (category 26), since a transverse crack is in effect a longitudinal crack when the bending axis is rotated 90 deg.

Vertical and longitudinal cracking (category 26)

17. Such cracks may be initiated by thermal or other volume changes, go through machinery openings or anchorages, or go to galleries or culverts.

Crack Widths, in.	Deduct Values
Very fine ≤0.01	10
Fine >0.01, ≤0.04	30
Medium >0.04, ≤0.08	50
Wide >0.08	70

There are no division B deduct values.

Diagonal cracking (category 27)

18. Diagonal cracking usually results from an overload. Such an

overload may result from structural distortion. Such cracks may be through an entire monolith, a partial monolith adjacent to shear keys between monoliths, a culvert wall or wall segment, or an anchorage. A crack bounding a spall created by compressive forces at a contraction joint should be evaluated as a spall.

Crack Widths, in.		Deduct Values
Very fine	≤0.01	20
Fine	>0.01, ≤0.04	40
Medium	>0.04, ≤0.08	60
Wide	>0.08	80

There are no division B deduct values.

Random cracking (category 28)

19. Random cracks may form in plastic or hardened concrete. It is advisable to thoroughly investigate such cracks to ensure that they are really random and not associated with embedded metal or trapped water freezing; in such cases, deduct values for a spall (category 36) are to be used.

Crack Widths, in.		Deduct Values
Very fine	≤0.01	10
Fine	>0.01, ≤0.04	20
Medium	>0.04, ≤0.08	40
Wide	>0.08	60

There are no division B deduct values.

Longitudinal floor
cracking (category 29)

20. Longitudinal floor cracks are evaluated only in reinforced U-Frame locks.

Crack Widths, in.		Deduct Values
Very fine	≤0.01	10
Fine	>0.01, ≤0.04	20
Medium	>0.04, ≤0.08	30
Wide	>0.08	40

For gate monoliths the division B deduct value is to be one half the above division A value.

Volume loss

21. A number of concrete-volume-loss categories are listed. Deduct values depend on estimated depth, extent, and location and may be taken from Figure 3. For volume losses on opposite sides of a monolith at the same elevation, add the deduct values for each volume loss to get one deduct value for volume loss at that elevation. For volume loss that occurs in a culvert wall, the percentage of depth is to be based on the total depth of concrete on both sides of the culvert. For gate monoliths with deficiencies near corners, appropriate division B deduct values should be established using the depth of division A as widths in division B and widths in A as the depth in division B.

22. Repairs generally require removal of additional concrete and replacement. Repairs are effective as long as they do not debond or otherwise deteriorate. When repairs have debonded, a deduction for the volume of the repair should be made.

Abrasion (category 31)

23. Abrasion generally results from solid particles in motion as a result of water flow; it can generally be limited by removal of debris. Deduct values from Figure 3 should be used. For abrasion within conduits, Table 2 should be used.

Table 2

Conduit Erosion Deduct Values

Depth, in.	Abrasion	Cavitation
≤3	10	20
>3 and ≤6	20	40
>6	30	60

Cavitation (category 32)

24. Cavitation results from the collapse of vapor bubbles in flowing water and is generally caused by high-velocity flow over abrupt changes in alignment. The cavitation causes additional changes in alignment. To prevent

further damage, repairs should be made promptly, and the cause should be eliminated. Deduct values from Table 2 are used.

Honeycomb (category 33)

25. Honeycomb generally results from poor concrete-placing practices and most frequently occurs at lift joints. Honeycomb may have been poorly repaired so that the repair has subsequently been easily removed by erosion. Deduct values from Figure 3 are used.

Pop-outs (category 34)

26. Pop-outs are generally caused by freezing of saturated porous aggregate particles but may also result from alkali-aggregate reaction. They are more aesthetically offensive than structurally serious. Deduct values from Figure 3 are used for walls. For decks, values for checking (category 21) are used.

Scaling (category 35)

27. Scaling is the flaking or sloughing away of the near-surface portion of concrete. It is usually caused by the development of osmotic and hydraulic pressures during freezing. Deduct values from Figure 3 are used for walls. For decks, values for checking (category 21) are used.

Spalling (category 36)

28. Spalling is the breaking away of a fragment, usually wedge or conical shaped, by the action of pressure or a blow. Structural distortion may apply sufficient pressure at contraction joints to cause spalls. Corrosion of reinforcing steel or other embedded metal may spall the concrete cover. Trapped water in voids may result in a spall. Deduct values from Figure 3 are used for walls. For a joint spall in a wall that is too small to affect structural integrity, a deduct value is to be made in division C. For decks, values for checking (category 21) are used.

Disintegration (category 37)

29. Disintegration may result from cycles of freezing and thawing, chemical attack, alkali-aggregate reaction, or other actions. It usually proceeds from categories 22, 23, or 35. Core sampling is generally essential to determine the actual depth of deterioration beyond the exposed surfaces and to determine cause. Deduct values from Figure 3 are used for walls. For decks, values for checking (category 21) are used.

Steel deterioration
(categories 41, 42, 43, and 44)

30. Corrosion and overloading are the two main causes of steel deterioration. Corrosion may be indicated initially by rust stains on concrete surfaces, but, except for high-strength steels, corrosion cannot be significant without the concrete cover delaminating or spalling. Exposed steel may have corroded sufficiently to have significantly reduced cross section. Reinforcing bars with exposed or partially exposed ends may not develop load. High-strength steel is susceptible to stress corrosion and may lose load capacity with little corrosion. For delamination or exposure of any area of reinforcing steel (category 43) serving a structural purpose, 30 points are deducted. If over 50 percent of the steel at a cross section is exposed or for any exposure or indicated corrosion of prestressing steel (category 43), 60 points are deducted. In division C, 5 points are deducted for slight corrosion stains, and 10 points are deducted for more general corrosion stains from reinforcing steel. For a slight amount of damaged armor (category 44), 5 points are deducted, and 10 points are deducted for more general damage to armor. One or two pieces missing or displaced and not a hazard should be considered as slight damage. For more than two pieces or any hazardous projections, the larger deduct is used.

Leakage and deposits
(categories 51 and 52)

31. Leakage (category 51) through cracks, joints, voids, and pores may affect the durability and function of a structure. Seeping water may increase concrete saturation, thus accelerating damage from cycles of freezing and thawing or producing mechanical failure during freezing. Deposits (category 52) left by evaporating water are formed by ions that have diffused out of the paste and weaken the concrete. Moving water may also erode backfill or foundation material. For seepage or for deposits of less than approximately 0.1 in., 5 points are deducted; and for leakage of up to approximately 10 gpm or for deposits up to approximately 0.5-in. thick, 10 points are deducted. Larger quantities should use a deduct of 20 points. It may be desirable to inspect a lock both full and empty to more accurately evaluate leakage.

APPENDIX A

GUIDE FOR MAKING A CONDITION SURVEY OF CONCRETE IN SERVICE

(Reported by ACI Committee 201)

ACI 201.1R-68

(Reaffirmed 1979)
From ACI JOURNAL, Nov. 1968

Guide for Making a Condition Survey of Concrete in Service

Reported by ACI Committee 201

This guide provides a system for reporting on the condition of concrete in service. It includes a check list of the many details to be considered in making a report, and provides standard definitions of 40 terms associated with the durability of concrete. Its purpose is to establish a uniform system for evaluating the condition of concrete.

Keywords: buildings; concrete construction; concrete durability; concrete pavements; concretes; corrosion; cracking (fracturing); deterioration; environment; freeze-thaw durability; inspection; joints; popouts; quality control; scaling; serviceability; spalling; strength; surveys (data collection).

APPENDIX

DEFINITION OF TERMS ASSOCIATED WITH THE DURABILITY OF CONCRETE

A.1 Cracks: An incomplete separation into one or more parts with or without space between.

A.1.1. Cracks will be classified by direction, width and depth. The following adjectives can be used: longitudinal, transverse, vertical, diagonal, and random. Three width ranges are suggested as follows: fine—generally less than 1 mm; medium—between 1 and 2 mm; wide—over 2 mm (see Fig. A.1.1.a through A.1.1.h).

A.1.2. *Pattern cracking:* Fine openings on concrete surfaces in the form of a pattern; resulting from a decrease in volume of the material near the surface, or increase in volume of the material below the surface, or both (see Fig. A.1.2.a through A.1.2.c).

A.1.3. *Checking:* Development of shallow cracks at closely spaced but irregular intervals on the surface of mortar or concrete (see Fig. A.1.3).

A.1.4. *Hairline cracking:* Small cracks of random pattern in an exposed concrete surface.

A.1.5. *D-cracking:* The progressive formation on a concrete surface of a series of fine cracks at rather close intervals, often of random patterns, but in highway slabs paralleling edges, joints, and cracks and usually curving across slab corners (see Fig. A.I.5.a and A.1.5.b).

A.2. Deterioration: Deterioration is any adverse change of normal mechanical, physical and chemical properties either on the surface or in the whole body of concrete generally through separation of its components.

A.2.1. *Disintegration:* Deterioration into small fragments or particles due to any cause (see Fig. A.2.1).

A.2.2. *Distortion:* Any abnormal deformation of concrete from its original shape (see Fig. A.2.2).

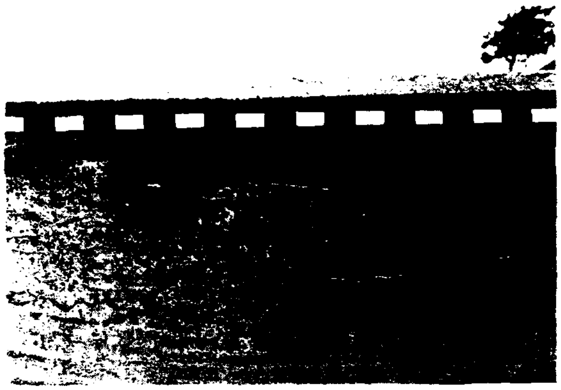


Fig. A.1.1.a—Longitudinal cracks (medium)

Fig. A.1.1.b—Transverse cracks (wide)

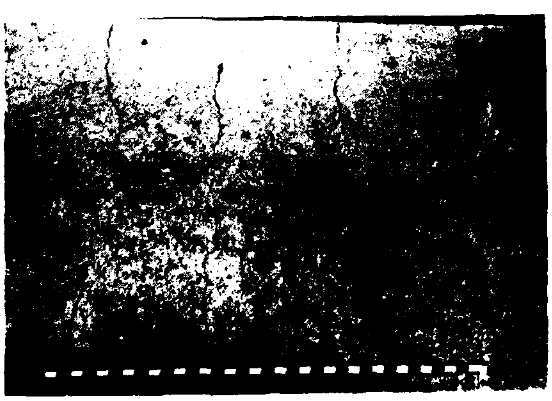


Fig. A.1.1.c—Transverse cracks (fine)

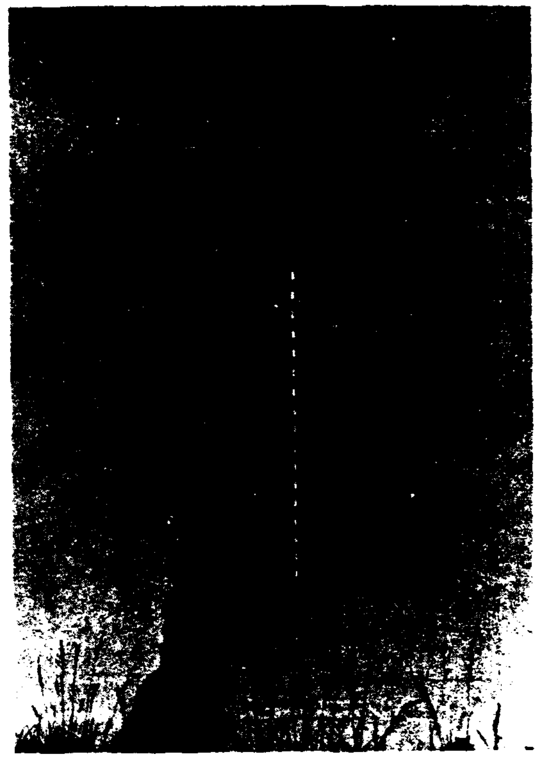


Fig. A.1.1.d—Vertical crack (medium)

Fig. A.1.1.e—Vertical crack (wide)

Fig. A.1.1.f—Diagonal cracks (wide)

Fig. A.1.1.g—Random cracks (wide)

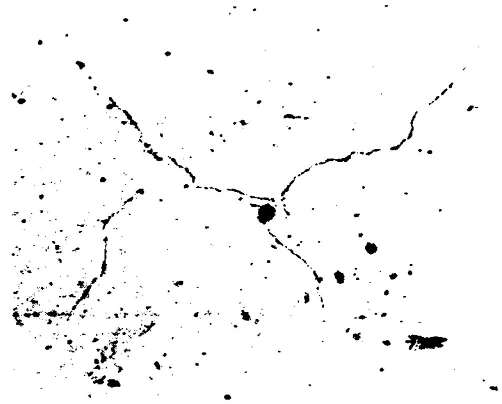


Fig. A.1.1.h—Random cracks (medium)

Fig. A.1.2.a—Pattern cracking (fine)

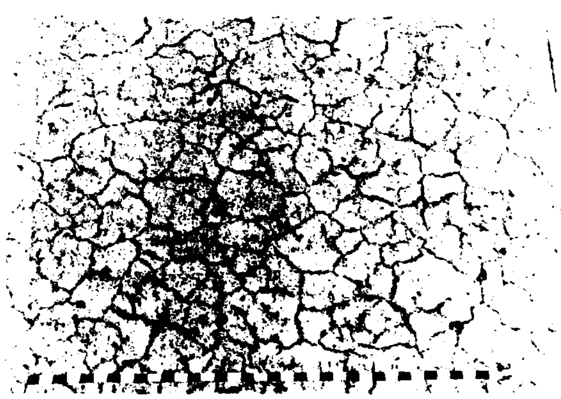


Fig. A.1.2.b—Pattern cracking (medium)

Fig.A.1.2.c—Pattern cracking (wide)

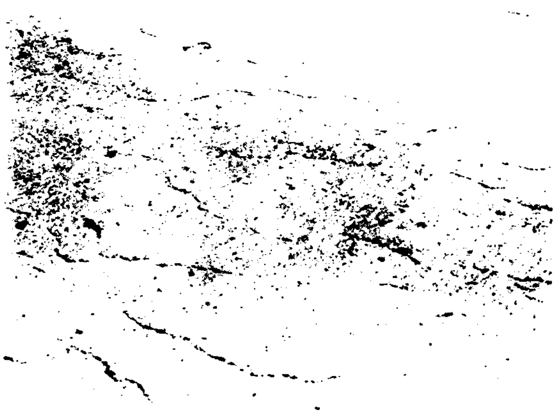


Fig. A.1.3—Checking (medium)

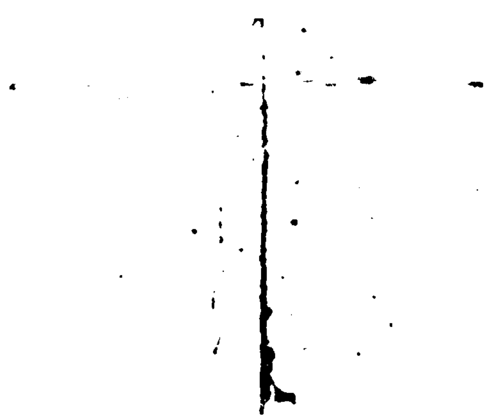


Fig. A.1.5.a—D-cracking (fine)

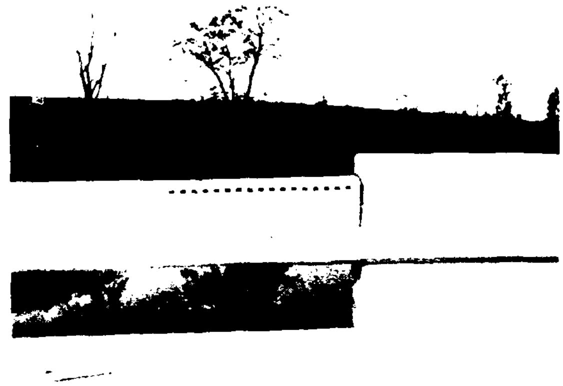


Fig. A.1.5.b—D-cracking (fine)

Fig. A.2.1—Disintegration

A.2.3. *Efflorescence*: A deposit of salts, usually white, formed on a surface, the substance having emerged from below the surface.

A.2.4. *Exudation*: A liquid or viscous gel-like material discharged through a pore, crack or opening in the surface (see Fig. A.2.4.a, A.2.4.b, and A.2.5).

A.2.5. *Incrustation*: A crust or coating generally hard formed on the surface of concrete or masonry construction (see Fig. A.2.5)

Fig. A.2.2—Distortion

Fig. A.2.4.b—Exudation

Fig. A.2.4.a—Exudation

Fig. A.2.5—Exudation and incrustation

A.2.6. *Pitting*: Development of relatively small cavities in a surface, due to phenomena such as corrosion or cavitation, or, in concrete, localized disintegration.

A.2.7. *Popout*: The breaking away of small portions of a concrete surface due to internal pressure which leaves a shallow, typical conical, depression (see Fig. A.2.7).

A.2.7.1. *Popouts, small:* Popouts leaving holes up to 10 mm in diameter, or the equivalent (see Fig. A.2.7.1).

A.2.7.2. *Popouts, medium:* Popouts leaving holes between 10 and 50 mm in diameter, or equivalent (see Fig. A.2.7.2).

A.2.7.3. *Popouts, large:* Popouts leaving holes greater than 50 mm in diameter, or the equivalent (see Fig. A.2.7.3).

A.2.8. *Erosion*: Deterioration brought about by the abrasive action of fluids or solids in motion (see Fig. A.2.8).

A.2.9. *Scaling*: Local flaking or peeling away of the near surface portion of concrete or mortar.

A.2.9.1. *Peeling*: A process in which thin flakes of mortar are broken away from a concrete surface; such as by deterioration or by adherence of surface mortar to forms as forms are removed (see Fig. A.2.9.1.a and A.2.9.1.b).

Fig. A.2.7—Popout

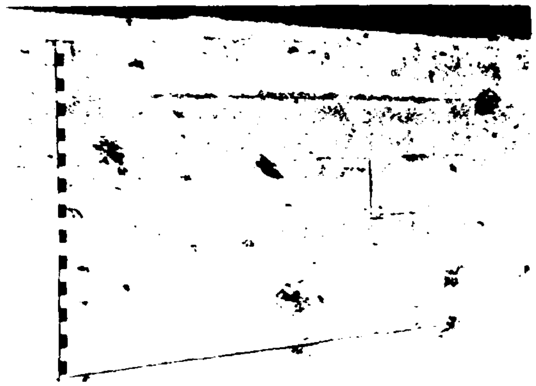


Fig. A.2.7.2—Popouts (medium)

Fig. A.2.7.1—Popouts (small)

Fig. A.2.7.3—Popouts (large)

A.2.9.2. *Scaling, light:* Loss of surface mortar without exposure of coarse aggregate (see Fig. A.2.9.2.a and A.2.9.2.b).

A.2.9.3. *Scaling, medium:* Loss of surface mortar up to 5 to 10 mm in depth and exposure of coarse aggregate (see Fig. A.2.9.3.a and A.2.9.3.b).

A.2.9.4. *Scaling, severe:* Loss of surface mortar 5 to 10 mm in depth with some loss of mortar surrounding aggregate particles 10 to 20 mm in

Fig. A.2.8—Erosion

depth, so that aggregate is clearly exposed and stands out from the concrete (see Fig. A.2.9.4.a and A.2.9.4.b).

A.2.9.5. *Scaling, very severe:* Loss of coarse aggregate particles as well as surface mortar and mortar surrounding aggregate, generally greater than 20 mm in depth (see Fig. A.2.9.5.a and A.2.9.5.b).

A.2.10. *Spall*: A fragment, usually in the shape of a flake, detached from a larger mass by a blow, by the action of weather, by pressure, or by expansion within the large mass.

A.2.10.1. *Small spall:* A roughly circular or oval depression generally not greater than 20 mm in depth nor greater than about 150 mm in any dimension, caused by the separation of a portion of the surface concrete (see Fig. A.2.10.1).

A.2.10.2. *Large spall:* May be roughly circular or oval depression, or in some cases an elongated depression over a reinforcing bar, generally 20 mm or more in depth and 150 mm or greater in any dimension, caused by a separation of the surface concrete (see Fig. A.2.10.2).

A.2.11. *Joint spall*: Elongated cavity along a joint (see Fig. A.2.11.a and A.2.11.b).

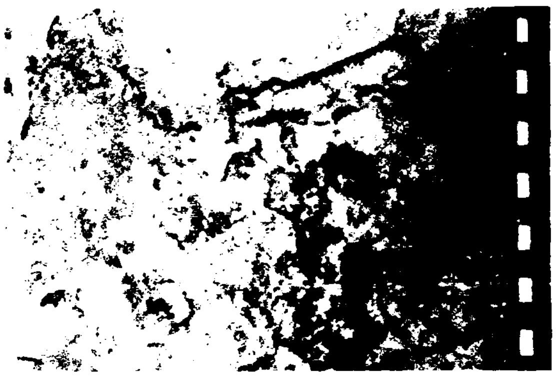


Fig. A.2.9.1.a—Close-up of peeling

Fig. A.2.9.1.b—Peeling on bridge abutment

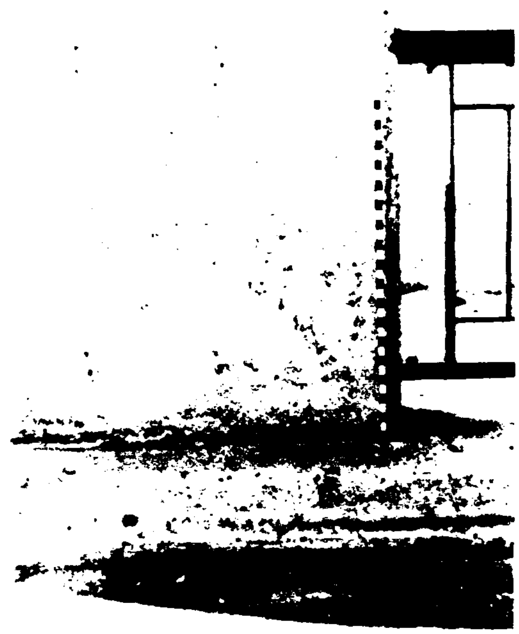


Fig. A.2.9.2.a—Scaling (light)

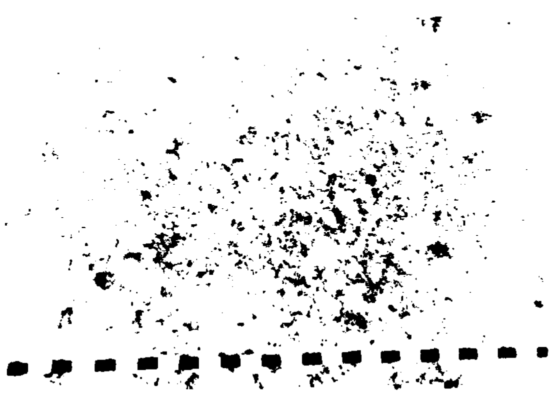


Fig. A.2.9.2.b—Close-up of scaling (light)

A.2.12. *Drummy area:* Area of concrete surface which gives off a hollow sound when struck.

A.2.13. *Stalactite*: A downward pointing formation, hanging from the surface of concrete, shaped like an icicle.

A.2.14. *Stalagmite*: As stalactite, but upward formation.

A.2.15. *Dusting*: The development of a powdered material at the surface of hardened concrete (see Fig. A.2.15).

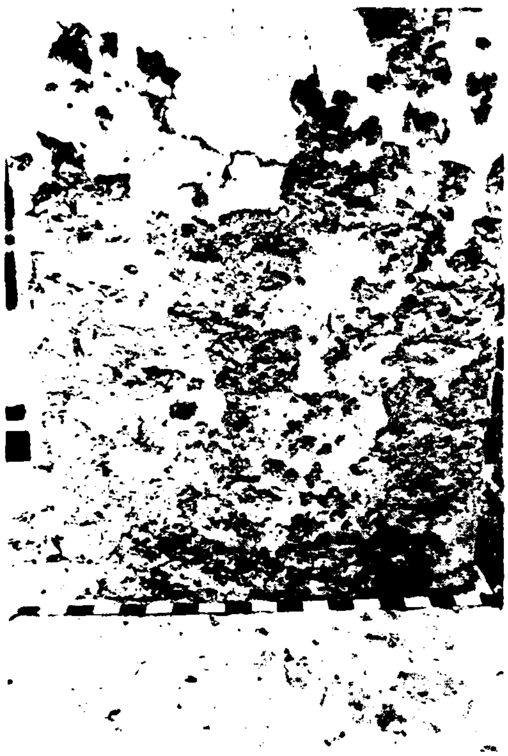


Fig. A.2.9.3.a—Scaling (medium)

Fig. A.2.9.4.b—Scaling severe

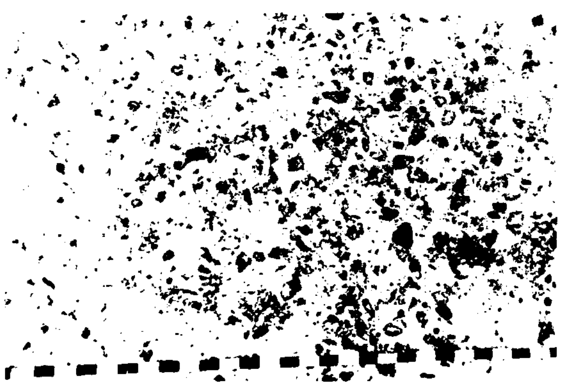


Fig. A.2.9.3.b—Close-up of scaling (medium)

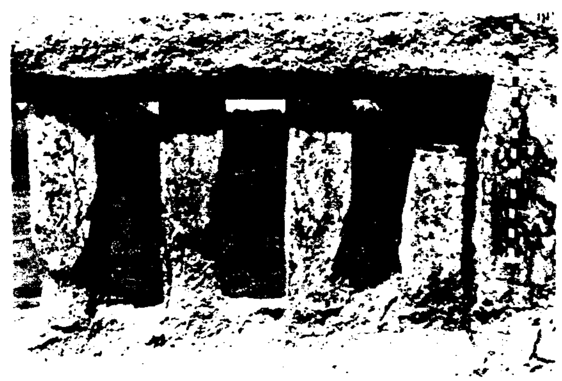


Fig. A.2.9.5.a—Scaling (very severe)

Fig. A.2.9.4.a—Close-up of scaling (severe)

Fig. A.2.9.5.b—Close-up of scaling (very severe)

Fig. A.2.10.1—Small spall

Fig. A.2.11.a—Joint spall

Fig. A.2.10.2—Large spall

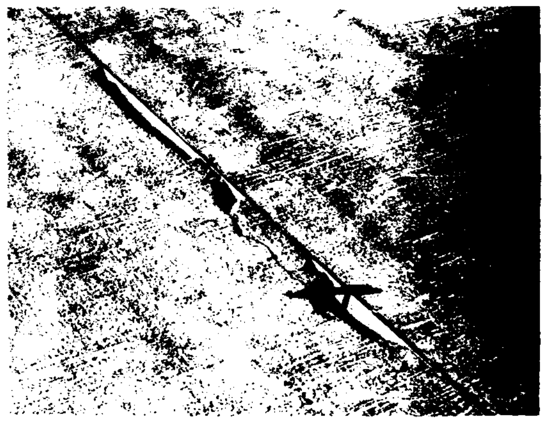


Fig. A.2.11.b—Joint spall

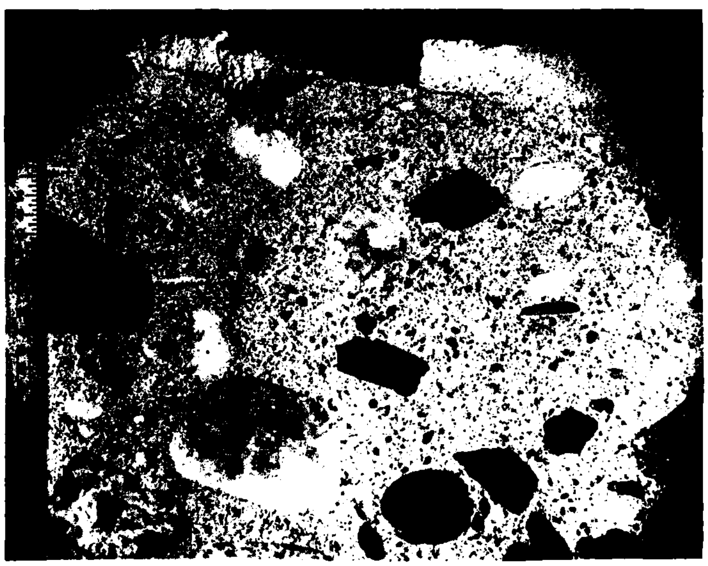


Fig. A.2.15—Dusting; surface at top of ruler is a floor surface of concrete placed *very* wet and which also carbonated; segregation is also evident

A.2.16. *Corrosion*: Disintegration or deterioration of concrete or reinforcement by electrolysis or by chemical attack (see Fig. A.2.16).

A.3. Textural defects:

A.3.1. *Bleeding channels:* Essentially vertical localized open channels caused by heavy bleeding (see Fig. A.3.1).

A.3.2. *Sand Streak*: Streak in surface of formed concrete caused by bleeding (see Fig. A.3.2).

A.3.3. *Water pocket*: Voids along the underside of aggregate particles or reinforcing steel which formed during the bleeding period. Initially filled with bleeding water.

A.3.4. *Stratification*: The separation of overwet or overvibrated concrete into horizontal layers with increasingly lighter material toward the top; water, laitance, mortar, and coarse aggregate will tend to occupy successively lower positions in that order; a layered structure in concrete resulting from placing of successive batches that differ in appearance (see Fig. A.3.4.).

A.3.5. *Honeycomb*: Voids left in concrete due to failure of the mortar to effectively fill the spaces among coarse aggregate particles (see Fig. A.3.5.a and A.3.5.b).

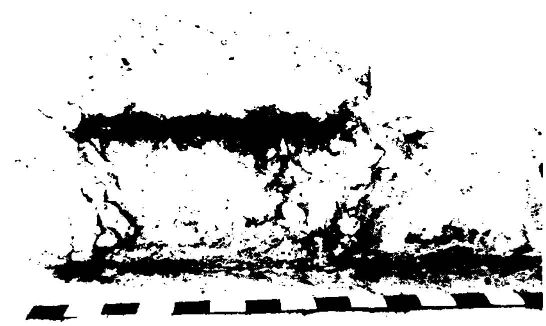


Fig. A.2.16—Corrosion

Fig. A.3.1—Bleeding channels and water pockets of concrete in a caisson; note laitance below particles of coarse aggregate

Fig. A.3.2—Sand streaking on a vertical formed surface

Fig. A.3.4—Stratification

Fig. A.3.5.a—Honeycomb

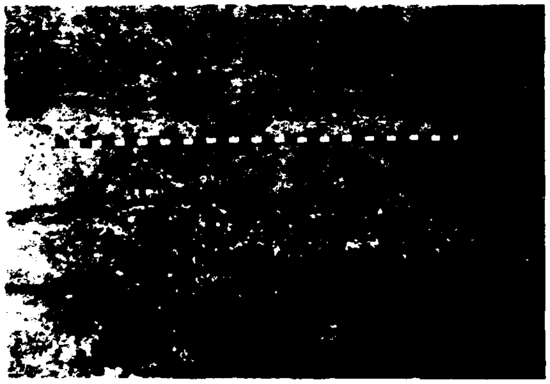


Fig. A.3.5.b—Honeycomb

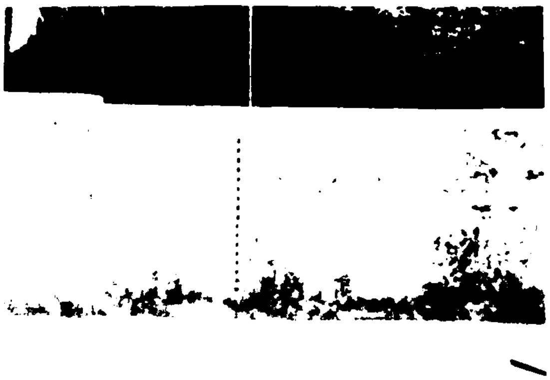


Fig. A.3.8—Discoloration

A.3.6. *Sand Pocket*: Part of concrete containing sand without cement.

A.3.7. *Segregation*: The differential concentration of the components of mixed concrete, resulting in non uniform proportions in the mass.

A.3.8. *Discoloration*: Departure of color from that which is normal or desired (see Fig. A.3.8).

REFERENCES

1. ACI Committee 116, "Cement and Concrete Terminology"—ACI 116R-78, American Concrete Institute, Detroit, 1978, 50 pp., Also, *ACI Manual of Concrete Practice*, Part 1.

2. Committee DB-5, "Standard Nomenclature and Definitions for Use in Pavement Inspection and Maintenance," Highway Research Board, Washington, D.C.

3. *Trilingual Dictionary of Engineering Materials Testing*, RILEM Bulletins 20-25, Paris, 1955.

This report was approved by letter ballot of the committee and reported to ACI headquarters Jan. 5, 1967. At the time of balloting (late 1966), the committee consisted of 22 members, of whom 19 voted affirmatively, 1 negatively, one "conditionally" affirmative, and one not returning his ballot.

APPENDIX B

SAMPLE MONOLITH INSPECTION FORMS

LOCK MONOLITH CONDITION INDEX CALCULATION FORM
EXAMPLE #1

Lock: CHARLIE Monolith#: 33

Date: 1/18/88 Inspector: REB Gate Block? yes no

Alignment Problems?: YES, ALKALI-AGG.

DISTRESS CATEGORIES:

CRACKING	DIVISION A: All Blocks — Deduct Values				DIVISION B: Gate Block — Additional Deducts			
	<=.01"	<=.04"	<=.08"	>.08	<=.01"	<=.04"	<=.08"	>.08
24 Horizontal EL 532	10	20	30	40	5	10	15	20
25 Vert & Transverse	10	20	30	40	-	10	20	30
26 Vert & Longitudinal	10	30	50	70	-	-	-	-
27 Diagonal	20	40	60	80	-	-	-	-
28 Random	10	20	40	60	-	-	-	-
29 Longit Floor	10	20	30	40	5	10	15	20

VOLUMETRIC CRACKING	%Width	%Depth	Deduct
21 Checking	100	10	50
22 D-Cracking	100	6	30
23 Pattern ALL ELEV	100	2	10
	50	10	25
VOLUME LOSS	50	6	15
31 Abrasion	50	2	5
33 Honeycomb	20	10	10
34 Pop-outs	20	6	6
35 Scaling	20	2	2
36 Spalling	Other:		
37 Disintegration	%Width	%Depth	Deduct
Deduct = (%W)*(%D)/20	100	4	20

Division B — Additional Deduct

The additional deduct value for volume loss type distress in gate blocks is equal to the deduct value computed in Division A.

Enter Deduct:_____

Enter MAX Div. B:_____

STEEL	Any Area	> 50% Area
42 Reinforcing (exposed)	30	60
43 Prestress (corrosion)	60	

CONDUITS	<= 3"	<= 6"	> 6"
31 Abrasion	10	20	30
32 Cavitation	20	40	60

Enter MAX Div. A: 30

DIVISION D: Decks

Categ	<25% Area	>25%
23	5	10
	5	10
	5	10

Enter SUM Div. D: 10

DIVISION C

OTHER	Deduct Values Light		Heavy
36 Spalled Joint	5		10
41 Corrosion Stains	5		10
44 Damaged Armor	5		10
LEAKAGE & DEPOSITS	Light	Moderate	Heavy
51 Leakage	5	10	20
52 Deposits	5	10	20

Sum Div C:_____<20 MAX

COMPUTE DEDUCT VALUE:

1) Max Div. A = 30
2) Max Div. B = _____
3) Sum Div. C = _____
4) Sum Div. D = 10

TOTAL DEDUCT = 40

C. I. RATING = 60

LOCK MONOLITH FIELD INSPECTION FORM
EXAMPLE #1

Lock: CHARLIE Monolith#: 33 L M R

Date: 1/18/88 Inspector: REB Gate Block? YES NO

Location Codes
L-Land Wall M-Intermediate Wall R-River Wall LS-Land Side Face RS-River Side Face D-Deck C-Conduit F-Floor

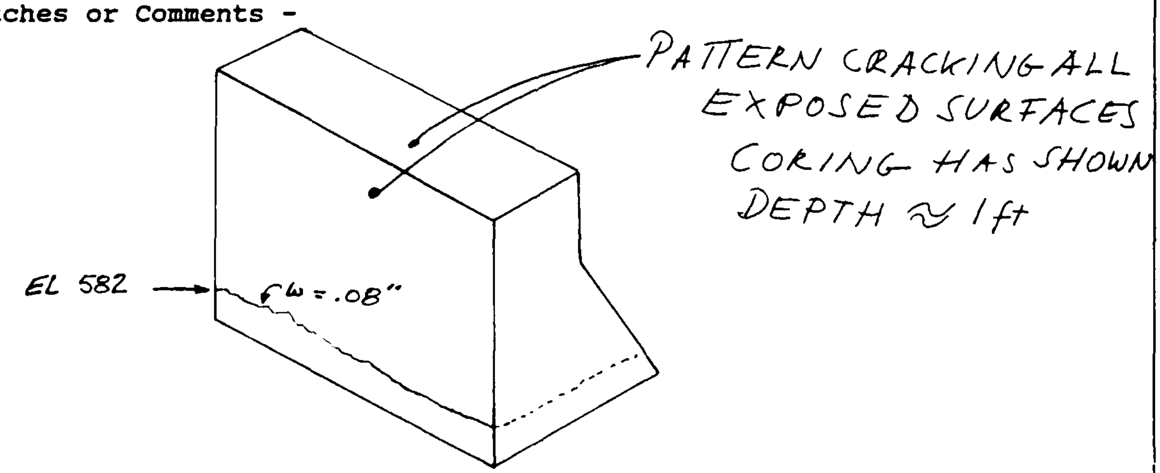
CRACKING
24-Horizontal 25-Vertical&Transverse 26-Vertical&Longitudinal 27-Diagonal 28-Random 29-Longitudinal Floor
1 Crack Category: 24 Width: .08 (in.) LS RS D C F
Remarks: ELEV 582
2 Crack Category: Width: (in.) LS RS D C F
Remarks:
3 Crack Category: Width: (in.) LS RS D C F
Remarks:
4 Crack Category: Width: (in.) LS RS D C F
Remarks:

VOLUME LOSS TYPE CRACKING / DETERIORATION
21-Checking 22-D-Cracking 23-Pattern 31-Abrasion 32-Cavitation 33-Honeycomb 34-Pop-Outs 35-Scaling 36-Spalling 37-Disintegration
1 Distress Category: 23 LS RS D C F
Distress: width ____ depth ≈ 1' height ____ elevs. ALL Section: width ____ depth ____ (at elevation of distress) Remarks: ALL EXPOSED SURFACES FROM ALKALI-AGGREGATE
2 Distress Category: LS RS D C F
Distress: width ____ depth ____ height ____ elevs. ____ Section: width ____ depth ____ (at elevation of distress) Remarks:
3 Distress Category: LS RS D C F
Distress: width ____ depth ____ height ____ elevs. ____ Section: width ____ depth ____ (at elevation of distress) Remarks:

Monolith#: 33

Location Codes						
LS-Land Side Face RS-River Side Face D-Deck C-Conduit F-Floor						
STEEL						
42-Reinforcing (exposed) O-Over 50% U-Under 50% Exposed at Section 43-Prestress (any exposure or indicated corrosion)						
42 43	LS RS D C F	O U	Remarks:			
42 43	LS RS D C F	O U				
42 43	LS RS D C F	O U				
OTHER						
36-Spalled Joint 41-Corrosion Stain 44-Damaged Armor LIT-Light HVY-Heavy						
36 41 44	LS RS	LIT HVY	Remarks:			
36 41 44	LS RS	LIT HVY				
36 41 44	LS RS	LIT HVY				
LEAKAGE & DEPOSITS						
51-Leakage 52-Deposits LIT-Light MOD-Moderate HVY-Heavy Moderate Leakage ≈ 10 gpm Moderate Deposit ≈ ½ inch thick						
51 52	LS RS C	LIT MOD HVY	Remarks:			
51 52	LS RS C	LIT MOD HVY				
51 52	LS RS C	LIT MOD HVY				

Sketches or Comments -



*-REMARKS: In all instances describe distress locations as completely as possible. Use the the monolith's deck, faces or joints as datums. When applicable, as in volume loss, distress width and depth may be expressed as percentages of section width or depth at given elevation. For volume loss in decks, indicate the percentage of the deck area that is affected.

LOCK MONOLITH CONDITION INDEX CALCULATION FORM
EXAMPLE #2

Lock: CHARLIE Monolith#: 37

Date: 1/18/88 Inspector: REB Gate Block? yes no

Alignment Problems?: Yes, ALKALI-AGG.

DISTRESS CATEGORIES:	DIVISION A: All Blocks				DIVISION B: Gate Block			
	Deduct Values				Additional Deducts			
CRACKING	<=.01"	<=.04"	<=.08"	>.08	<=.01"	<=.04"	<=.08"	>.08
24 Horizontal 650-658	10	20	30	40	5	10	15	20
25 Vert & Transverse	10	20	30	40	-	10	20	30
26 Vert & Longitudinal	10	30	50	70	-	-	-	-
27 Diagonal	20	40	60	80	-	-	-	-
28 Random	10	20	40	60	-	-	-	-
29 Longit Floor	10	20	30	40	5	10	15	20

VOLUMETRIC CRACKING	%Width	%Depth	Deduct
21 Checking	100	10	50
22 D-Cracking	100	6	30
23 Pattern ALL ELEV	100	2	10
	50	10	25
VOLUME LOSS	50	6	15
31 Abrasion	50	2	5
33 Honeycomb	20	10	10
34 Pop-outs	20	6	6
35 Scaling	20	2	2
36 Spalling	Other:		
37 Disintegration	%Width	%Depth	Deduct
Deduct = (%W)*(%D)/20	100	4	20

Additional Deduct

The additional deduct value for volume loss type distress in gate blocks is equal to the deduct value computed in Division A.

Enter Deduct: 20

Enter MAX Div. B: 20

STEEL	Any Area	> 50% Area
42 Reinforcing (exposed)	30	60
43 Prestress (corrosion)	60	

CONDUITS	<= 3"	<= 6"	> 6"
31 Abrasion	10	20	30
32 Cavitation	20	40	60

Enter MAX Div. A: 30

DIVISION D: Decks

Categ	<25% Area	>25%
23	5	10
	5	10
	5	10

Enter SUM Div. D: 10

DIVISION C

OTHER	Deduct Values Light		Heavy
36 Spalled Joint	5		10
41 Corrosion Stains	5		10
44 Damaged Armor	5		10
LEAKAGE & DEPOSITS	Light	Moderate	Heavy
51 Leakage	5	10	20
52 Deposits	5	10	20

Sum Div C:_____<20 MAX

COMPUTE DEDUCT VALUE:

1) Max Div. A = 30
2) Max Div. B = 20
3) Sum Div. C =
4) Sum Div. D = 10

TOTAL DEDUCT = 60

C. I. RATING = 40

LOCK MONOLITH FIELD INSPECTION FORM
EXAMPLE NO 2

Lock: CHARLIE Monolith#: 37 L M R

Date: 1/18/88 Inspector: KEB Gate Block? YES NO

Location Codes L-Land Wall M-Intermediate Wall R-River Wall LS-Land Side Face RS-River Side Face D-Deck C-Conduit F-Floor
CRACKING
24-Horizontal 25-Vertical&Transverse 26-Vertical&Longitudinal 27-Diagonal 28-Random 29-Longitudinal Floor
1 Crack Category: 24 Width: .06 (in.) LS RS D C F
Remarks: ELEV VARIES FROM 650(RS) TO 658(LS)
2 Crack Category: Width: (in.) LS RS D C F
Remarks:
3 Crack Category: Width: (in.) LS RS D C F
Remarks:
4 Crack Category: Width: (in.) LS RS D C F
Remarks:
VOLUME LOSS TYPE CRACKING / DETERIORATION
21-Checking 22-D-Cracking 23-Pattern 31-Abrasion 32-Cavitation 33-Honeycomb 34-Pop-Outs 35-Scaling 36-Spalling 37-Disintegration
1 Distress Category: 23 LS RS D C F
Distress: width ____ depth ≈1'' height ____ elevs. ALL Section: width ____ depth ____ (at elevation of distress) Remarks: ALL EXPOSED SURFACES FROM ALKALI-AGGREGATE REACTION
2 Distress Category: LS RS D C F
Distress: width ____ depth ____ height ____ elevs. ____ Section: width ____ depth ____ (at elevation of distress) Remarks:
3 Distress Category: LS RS D C F
Distress: width ____ depth ____ height ____ elevs. ____ Section: width ____ depth ____ (at elevation of distress) Remarks:

Monolith#: 37

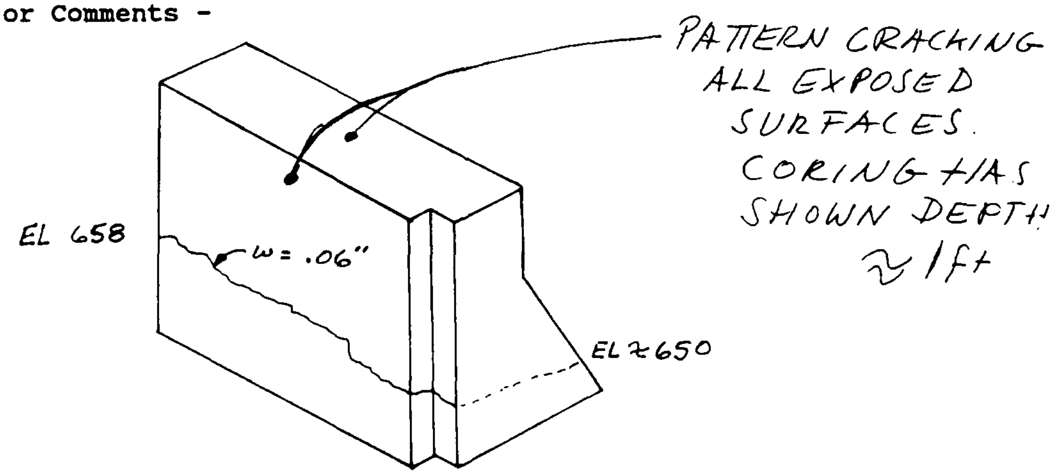
Location Codes LS-Land Side Face RS-River Side Face D-Deck C-Conduit F-Floor

STEEL			
42-Reinforcing (exposed) O-Over 50% U-Under 50% Exposed at Section 43-Prestress (any exposure or indicated corrosion)			
42 43	LS RS D C F	O U	Remarks:
42 43	LS RS D C F	O U	
42 43	LS RS D C F	O U	

OTHER			
36-Spalled Joint 41-Corrosion Stain 44-Damaged Armor LIT-Light HVY-Heavy			
36 41 44	LS RS	LIT HVY	Remarks:
36 41 44	LS RS	LIT HVY	
36 41 44	LS RS	LIT HVY	

LEAKAGE & DEPOSITS			
51-Leakage 52-Deposits LIT-Light MOD-Moderate HVY-Heavy Moderate Leakage ≈ 10 gpm Moderate Deposit ≈ ½ inch thick			
51 52	LS RS C	LIT MOD HVY	Remarks:
51 52	LS RS C	LIT MOD HVY	
51 52	LS RS C	LIT MOD HVY	

Sketches or Comments -



*-REMARKS: In all instances describe distress locations as completely as possible. Use the the monolith's deck, faces or joints as datums. When applicable, as in volume loss, distress width and depth may be expressed as percentages of section width or depth at given elevation. For volume loss in decks, indicate the percentage of the deck area that is affected.

LOCK MONOLITH CONDITION INDEX CALCULATION FORM
EXAMPLE #3

Lock: CHARLIE Monolith#: 48
Date: 1/18/88 Inspector: REB Gate Block? yes no
Alignment Problems?: YES, ALKALI-AGG

DISTRESS CATEGORIES:

DISTRESS CATEGORIES	DIVISION A: All Blocks				DIVISION B: Gate Block			
	Deduct Values				Additional Deducts			
CRACKING	<=.01"	<=.04"	<=.08"	>.08	<=.01"	<=.04"	<=.08"	>.08
24 Horizontal EL 656	10	20	30	40	5	10	15	20
25 Vert & Transverse	10	20	30	40	-	10	20	30
26 Vert & Longitudinal	10	30	50	70	-	-	-	-
27 Diagonal	20	40	60	80	-	-	-	-
28 Random	10	20	40	60	-	-	-	-
29 Longit Floor	10	20	30	40	5	10	15	20

VOLUMETRIC CRACKING	%Width	%Depth	Deduct
21 Checking	100	10	50
22 D-Cracking	100	6	30
23 Pattern ALL ELEV	100	2	10
	50	10	25
VOLUME LOSS	50	6	15
31 Abrasion	50	2	5
33 Honeycomb	20	10	10
34 Pop-outs	20	6	6
35 Scaling	20	2	2
36 Spalling	Other:		
37 Disintegration	%Width	%Depth	Deduct
Deduct = (%W)*(%D)/20	100	4	20

Additional Deduct

The additional deduct value for volume loss type distress in gate blocks is equal to the deduct value computed in Division A.

Enter Deduct: ____

Enter MAX Div. B: ____

STEEL	Any Area	> 50% Area
42 Reinforcing (exposed)	30	60
43 Prestress (corrosion)	60	

CONDUITS	<= 3"	<= 6"	> 6"
31 Abrasion	10	20	30
32 Cavitation	20	40	60

Enter MAX Div. A: 50

DIVISION D: Decks

Categ	<25% Area	>25%
23	5	10
	5	10
	5	10

Enter SUM Div. D: 10

DIVISION C

OTHER	Deduct Values Light		Heavy
36 Spalled Joint	5		10
41 Corrosion Stains	5		10
44 Damaged Armor	5		10
LEAKAGE & DEPOSITS	Light	Moderate	Heavy
51 Leakage	5	10	20
52 Deposits	5	10	20

Sum Div C: 10 <20 MAX

COMPUTE DEDUCT VALUE:

1) Max Div. A = 50
2) Max Div. B = ____
3) Sum Div. C = 10
4) Sum Div. D = 10

TOTAL DEDUCT = 70

C. I. RATING = 30

LOCK MONOLITH FIELD INSPECTION FORM

EXAMPLE #3

Lock: CHARLIE Monolith#: 48 L M R

Date: 1/18/88 Inspector: REB Gate Block? YES NO

Location Codes
L-Land Wall M-Intermediate Wall R-River Wall
LS-Land Side Face RS-River Side Face D-Deck C-Conduit F-Floor

CRACKING

24-Horizontal 25-Vertical&Transverse 26-Vertical&Longitudinal
27-Diagonal 28-Random 29-Longitudinal Floor

1 Crack Category: 24 Width: .05 (in.) LS RS D C F

Remarks: ELEV 656

2 Crack Category: 26 Width: .06 (in.) LS RS D C F

Remarks: 9 TO 11 FT FROM RS FACE

3 Crack Category: Width: (in.) LS RS D C F

Remarks:

4 Crack Category: Width: (in.) LS RS D C F

Remarks:

VOLUME LOSS TYPE CRACKING / DETERIORATION

21-Checking 22-D-Cracking 23-Pattern 31-Abrasion 32-Cavitation
33-Honeycomb 34-Pop-Outs 35-Scaling 36-Spalling 37-Disintegration

1 Distress Category: 23 LS RS D C F

Distress: width ____ depth ≈1' height ____ elevs. ALL
Section: width ____ depth ____ (at elevation of distress)
Remarks: ALL EXPOSED SURFACES FROM ALKALI-AGGREGATE REACTION

2 Distress Category: LS RS D C F

Distress: width ____ depth ____ height ____ elevs. ____
Section: width ____ depth ____ (at elevation of distress)
Remarks:

3 Distress Category: LS RS D C F

Distress: width ____ depth ____ height ____ elevs. ____
Section: width ____ depth ____ (at elevation of distress)
Remarks:

Monolith#: 48

Location Codes				
LS-Land Side Face	**RS**-River Side Face	**D**-Deck	**C**-Conduit	**F**-Floor

STEEL

42-Reinforcing (exposed) **O**-Over 50% **U**-Under 50% Exposed at Section
43-Prestress (any exposure or indicated corrosion)

42 43	LS RS D C F	O U	Remarks:
42 43	LS RS D C F	O U	
42 43	LS RS D C F	O U	

OTHER

36-Spalled Joint **41**-Corrosion Stain **44**-Damaged Armor **LIT**-Light **HVY**-Heavy

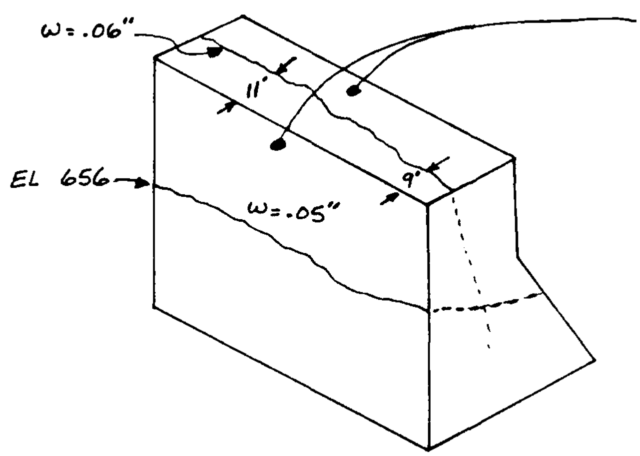
36 41 44	LS RS	LIT HVY	Remarks:
36 41 44	LS RS	LIT HVY	
36 41 44	LS RS	LIT HVY	

LEAKAGE & DEPOSITS

51-Leakage **52**-Deposits **LIT**-Light **MOD**-Moderate **HVY**-Heavy
Moderate Leakage ≈ 10 gpm Moderate Deposit ≈ ⅛ inch thick

51 52	LS RS C	LIT MOD HVY	Remarks: FROM EL 658 CRACK NEAR UPSTREAM JT
51 52	LS RS C	LIT MOD HVY	
51 52	LS RS C	LIT MOD HVY	

Sketches or Comments -



PATTERN CRACKING ALL EXPOSED SURFACES

CORING HAS SHOWN DEPTH ≈ 1 FT

*-REMARKS: In all instances describe distress locations as completely as possible. Use the the monolith's deck, faces or joints as datums. When applicable, as in volume loss, distress width and depth may be expressed as percentages of section width or depth at given elevation. For volume loss in decks, indicate the percentage of the deck area that is affected.

LOCK MONOLITH CONDITION INDEX CALCULATION FORM
EXAMPLE #4

Lock: DOG Monolith#: M21

Date: 1/18/88 Inspector: REB Gate Block? yes no

Alignment Problems?: No

DISTRESS CATEGORIES:	DIVISION A: All Blocks				DIVISION B: Gate Block			
	Deduct Values				Additional Deducts			
CRACKING	<=.01"	<=.04"	<=.08"	>.08	<=.01"	<=.04"	<=.08"	>.08
24 Horizontal	10	20	30	40	5	10	15	20
25 Vert & Transverse	10	20	30	40	-	10	20	30
26 Vert & Longitudinal	10	30	50	70	-	-	-	-
27 Diagonal	20	40	60	80	-	-	-	-
28 Random	10	20	40	60	-	-	-	-
29 Longit Floor	10	20	30	40	5	10	15	20

VOLUMETRIC CRACKING	%Width	%Depth	Deduct
21 Checking	100	10	50
22 D-Cracking	100	6	30
23 Pattern	100	2	10
	50	10	25
VOLUME LOSS	50	6	15
31 Abrasion	50	2	5
33 Honeycomb	20	10	10
34 Pop-outs	20	6	6
35 Scaling EL 680-695	20	2	2
36 Spalling	Other:		
37 Disintegration	%Width	%Depth	Deduct
Deduct = (%W)*(%D)/20	____	____	____

Division B — Additional Deduct

The additional deduct value for volume loss type distress in gate blocks is equal to the deduct value computed in Division A.

Enter Deduct: 10

Enter MAX Div. B: 10

STEEL	Any Area	> 50% Area
42 Reinforcing (exposed)	30	60
43 Prestress (corrosion)	60	

CONDUITS	<= 3"	<= 6"	> 6"
31 Abrasion	10	20	30
32 Cavitation	20	40	60

Enter MAX Div. A: 10

DIVISION D: Decks

Categ	<25% Area	>25%
	5	10
35	5	10
	5	10

Enter SUM Div. D: 10

DIVISION C

OTHER	Deduct Values Light		Heavy
36 Spalled Joint	5		10
41 Corrosion Stains	5		10
44 Damaged Armor	5		10
LEAKAGE & DEPOSITS	Light	Moderate	Heavy
51 Leakage	5	10	20
52 Deposits	5	10	20

Sum Div C: 10 <20 MAX

COMPUTE DEDUCT VALUE:

1) Max Div. A = 10
2) Max Div. B = 10
3) Sum Div. C = 10
4) Sum Div. D = 10

TOTAL DEDUCT = 40

C. I. RATING = 60

LOCK MONOLITH FIELD INSPECTION FORM

EXAMPLE #4

Lock: DOG Monolith#: M21 L M R

Date: 1/18/88 Inspector: REB Gate Block? YES NO

Location Codes
L-Land Wall M-Intermediate Wall R-River Wall
LS-Land Side Face RS-River Side Face D-Deck C-Conduit F-Floor

CRACKING

24-Horizontal 25-Vertical&Transverse 26-Vertical&Longitudinal
27-Diagonal 28-Random 29-Longitudinal Floor

1	Crack Category:	Width: (in.)	LS	RS	D	C	F
Remarks:							
2	Crack Category:	Width: (in.)	LS	RS	D	C	F
Remarks:							
3	Crack Category:	Width: (in.)	LS	RS	D	C	F
Remarks:							
4	Crack Category:	Width: (in.)	LS	RS	D	C	F
Remarks:							

VOLUME LOSS TYPE CRACKING / DETERIORATION

21-Checking 22-D-Cracking 23-Pattern 31-Abrasion 32-Cavitation
33-Honeycomb 34-Pop-Outs 35-Scaling 36-Spalling 37-Disintegration

1 Distress Category: 35 LS RS D C F

Distress: width 100% depth 6" height ______ elevs. 680-695
Section: width ______ depth ______ (at elevation of distress)
Remarks:

2 Distress Category: LS RS D C F

Distress: width ______ depth ______ height ______ elevs. ______
Section: width ______ depth ______ (at elevation of distress)
Remarks:

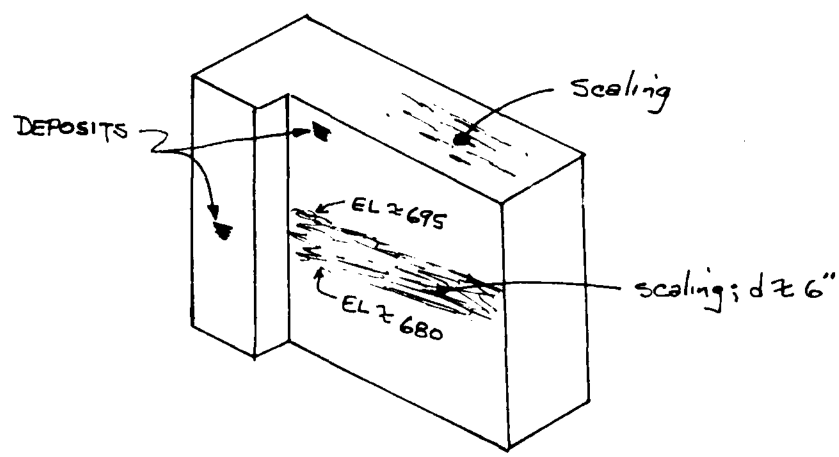
3 Distress Category: LS RS D C F

Distress: width ______ depth ______ height ______ elevs. ______
Section: width ______ depth ______ (at elevation of distress)
Remarks:

Monolith#: M21

Location Codes LS-Land Side Face RS-River Side Face D-Deck C-Conduit F-Floor			
STEEL			
42-Reinforcing (exposed) O-Over 50% U-Under 50% Exposed at Section 43-Prestress (any exposure or indicated corrosion)			
42 43	LS RS D C F	O U	Remarks:
42 43	LS RS D C F	O U	
42 43	LS RS D C F	O U	
OTHER			
36-Spalled Joint 41-Corrosion Stain 44-Damaged Armor LIT-Light HVY-Heavy			
36 41 44	LS RS	LIT HVY	Remarks:
36 41 44	LS RS	LIT HVY	
36 41 44	LS RS	LIT HVY	
LEAKAGE & DEPOSITS			
51-Leakage 52-Deposits LIT-Light MOD-Moderate HVY-Heavy Moderate Leakage ≈ 10 gpm Moderate Deposit ≈ ½ inch thick			
51 52	LS RS C	LIT MOD HVY	Remarks:
51 52	LS RS C	LIT MOD HVY	
51 52	LS RS C	LIT MOD HVY	

Sketches or Comments -



*-REMARKS: In all instances describe distress locations as completely as possible. Use the the monolith's deck, faces or joints as datums. When applicable, as in volume loss, distress width and depth may be expressed as percentages of section width or depth at given elevation. For volume loss in decks, indicate the percentage of the deck area that is affected.

APPENDIX C

FIELD TEST TRIP REPORTS

CEWES-SC-A 12 December 1986

MEMORANDUM FOR RECORD

SUBJECT: Trip Report - Lock & Dam No. 20, Upper Mississippi, to Evaluate Concrete Condition Index System for Locks

Background:

1. Part of the effort under the Operations Management Problem Area of the REMR Research Program is to develop condition index systems for the US Army Engineer Waterways Experiment Station (WES) civil works structures. Systems are currently under development for lock miter gates, sheet piling, and concrete lock walls. The Concrete Lock Wall Condition Index System is being developed under contract by the Tennessee Valley Authority (TVA). The contract is being managed by the Concrete Technology Division of the Structures Laboratory at WES for the Construction Engineering Research Laboratory (CERL), which is responsible for the Operations Management Problem Area. A proposed system has been developed by TVA, and the purpose of the trip to Lock and Dam No. 20 was to apply the system to that lock.

Objective:

2. The objective was to evaluate the condition index system developed by TVA for concrete lock walls at a lock project and to make any adjustments or refinements deemed necessary. Factors to be considered in the evaluations were as follows:

a. Does the system produce consistent results, and is it independent of the inspector using the system?

b. Does it account for all the types of deficiencies possible in the concrete of a navigation lock?

c. Are the types of deficiencies properly weighted so that the more serious deficiencies result in a lower condition index number?

d. Is the system easy to use, and will it be accepted by field personnel?

Evaluation:

3. Lock and Dam No. 20, Upper Mississippi was visited on 2-4 December 1986 (a list of participants is provided as enclosure 1). The morning of the first day was devoted to reviewing the proposed condition index system. The purpose of the review was to acquaint the participants with the system and the logic used in its development. Mr. Rupert Bullock, who developed the system, led the discussion and explained how the rating system was envisioned to work. A discussion of the various deficiencies and their deduct values followed with some recommendations for changes to the text to clarify some of the deficiencies and procedures. One additional deficiency (protruding or missing armor)

was identified with a recommendation for including it in the system along with a deduct value.

4. After lunch, a cursory review of the condition of the lock wall monoliths lead to the selection of seven monoliths to be evaluated using the condition index system. Two gate monoliths and six interior monoliths were chosen. The required forms used to record the deficiencies of the monoliths were distributed to the participants along with a crack measuring gage. Mr. Bullock discussed the types of deficiencies and their deduct values for the horizontal surface of lock monolith number 22. After a few questions and a short discussion period, each participant was on his own to evaluate the horizontal surfaces of the other monoliths.

5. The morning of the second day was used to record the deficiencies of the vertical lock walls of the selected monoliths. This task was accomplished from a small boat inside the lock which was moved alongside the walls to enable the measurement of cracks and spalled areas. Deposits, missing armor, and other deficiencies were recorded.

6. The afternoon session was used to determine a condition index number for the monoliths chosen for evaluation. The results are shown in Table 1. There were a few incidences of large discrepancies in the values obtained by different inspectors, but these were quickly resolved by a second visit to the monoliths in question, along with some additional measurements. The discrepancies were not the fault of the system but were found to be the result of errors in measurement or procedure by the inspectors. It was felt that these errors would be eliminated or minimized as experience was gained by the inspectors.

7. After some hands-on experience with the proposed system and a review of the results obtained on the seven monoliths chosen for evaluation at Lock and Dam No. 20, the participants reached the following conclusions:

a. The proposed system produces a quantitative value for the condition of a concrete lock monolith that is reproducible and independent of the inspector.

b. The proposed system produced index numbers that could be used to rank the condition of the monoliths evaluated. The inspectors agreed with the ranking developed by the system (i.e. monoliths #3, 22, 4A, 38, 18A and 15, in the order of worst to best).

c. There are advantages to a system which produces a representative quantitative value for the condition of the concrete of a lock monolith and a lock. These advantages may outweigh the increase in time required to conduct a survey with this system over the normal periodic inspection procedure.

d. Additional field trials should be conducted before the system is recommended for adoption.

Recommended Additional Work:

8. The morning of 4 December 1986 was used to discuss and plan future efforts on the Concrete Lock Wall Condition Index System. Everyone felt that more field testing at different locks should be conducted before the system is proposed for adoption. Three or four more field evaluations should be conducted to include locks with many different types of deficiencies. Suggestions included a high lift lock, a dewatered lock, a lock in the Ohio River Division, and a lock in the South.

9. It was decided that the text for the condition index system should be revised to address more clearly the areas in which questions were raised during the discussion of the system. An attempt should also be made to obtain original photographs of all pictures used in the text for reproduction purposes, and the text should be put in the same format as other REMR reports.

10. Jerry Wickersham stated that there were three locks within the Rock Island District for which they had completed concrete condition surveys. He stated that it may be possible to extract the necessary data from these surveys to compute a condition index for the lock wall monoliths using the proposed condition index system. This process would yield data to do some statistical analysis on arriving at an overall condition index number for a lock. The data could be used to determine the number of randomly selected monoliths that must be evaluated to arrive with a high level of confidence at an overall rating for the lock. In addition, it would provide base level index numbers for the locks and their monoliths for future use. Jerry is to check with his District to see if it is possible for him to squeeze this work into his schedule.

11. Future field evaluations should be conducted in much the same manner as the evaluation at Lock No. 20. The evaluations should be used to acquaint different field personnel with the proposed system, give them some hands-on experience in using the system, and provide them the opportunity to comment on the system and recommend improvement.

2 Encls

WILLIAM F. MCCLEESE
REMR Program Manager

Concrete Lock Wall Condition Index System

Evaluation Team

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   Construction Engineering Research Laboratory
   Tele: (217) 352-7471

Table 1

Condition Index Number for Lock Wall Monoliths

Lock and Dam No. 20

Inspector	Lock Wall Monolith Number						
	3	4A	15	18A	21	22	38
McCleese	35	50	80	70	65	33	-
Bullock	35	60	75	75	60	45	70
Huston	35	60	75	75	20*	45	60
Wickersham	30	60	75	65	60	35	70
Yu	30	50	75	70	60	35	60
Foster	30	60	75	65	65	47	70
Clark	30	60	75	60	60	45	60
Average	32.1	57.1	75.7	68.6	*	40.7	65.0
Std. Deviation	2.47	4.52	1.75	5.19	*	5.60	5.00

* The discrepancy in the condition index value for monolith No. 21 was the result of a large vertical and longitudinal crack in the monolith which rated a deduct value of 70. The crack was located below a grate on the horizontal surface of the monolith. Although the crack was observed on the horizontal surface by all inspectors, only one noted that its width on the vertical surface beneath the grating was much wider. The monolith was revisited by all inspectors, and all agreed that the deduct value for the crack should be 70, which would yield a condition index value of 30 or below.

CEWES-SC-A 1 October 1987

MEMORANDUM FOR RECORD

SUBJECT: Trip Report - Port Allen Lock to Evaluate a Concrete Condition Index System for Locks

Background:

1. Part of the effort under the Operations Management Problem Area of the REMR Research Program is to develop condition index systems for the US Army Corps of Engineers Waterways Experiment Station (WES) civil works structures. A concrete lock wall condition index system has been developed by Mr. Rupert Bullock under contract to WES. The system was field tested at Lock and Dam No. 20, Upper Mississippi River, in December 1986 and at Dashields Locks and Dam, Ohio River, in July 1987. The results from these two field tests were very promising. However, both of these structures were low-lift gravity structures, and the lock chambers were not dewatered at the time of the inspection. It was still desirable to test the system on other structures with dewatered lock chambers. Contact with the Lower Mississippi Valley Division resulted in the selection of Port Allen Lock as a test for the condition index system.

2. Port Allen Lock is a U-frame structure located at Port Allen, LA, and is part of the Gulf Intracoastal Waterway System. The lock was dewatered for inspection, and this was the first opportunity to try the concrete condition index system on a dewatered structure. This was also the first time the system was used on other than a gravity structure, and there was some concern over whether it would be applicable and produce meaningful results.

Objective:

3. The objective was to evaluate the condition index system for rating the concrete in the lock walls at a Port Allen Lock. Factors to be considered in the evaluation were the following:

a. Does the system produce consistent results, and is it independent of the inspector using the system?

b. Does it account for all the types of deficiencies possible in the concrete of a U-frame navigation lock?

c. Are the types of deficiencies properly weighted so that the more serious deficiencies result in a lower condition index number?

d. Can this system be used for rating the condition of the concrete in a U-frame lock?

e. Is the system easy to use, and will it be accepted by field personnel?

4. A secondary objective was to provide personnel within the Lower Mississippi Valley Division training in the use of the system and to obtain their input for improvements to the system.

Evaluation:

5. Port Allen Lock was visited on 17-18 September 1987. (A list of participants is provided as enclosure 1.) The morning of the first day was devoted to reviewing the proposed condition index system and selecting lock wall monoliths for the test. The review session was to acquaint the participants with the system and the logic used in its development. Mr. Rupert Bullock lead the discussion and explained how the rating system was envisioned to work. There were some general concerns over the use of the index numbers derived from this system and how they would be used. The concern was that the system only assesses the condition of the concrete in the lock, and the condition index number is only for the concrete and not representative of the overall condition of the lock. While those who conduct the survey and others thoroughly familiar with the system would realize this fact, others more removed from the rating system and the lock may see these numbers and take them to represent the overall condition index for the lock. It was agreed that the documentation for the condition index system should clearly explain that it addresses only the condition of the concrete and that other condition index systems or methods are needed to assess the condition of other aspects of the lock such as the foundation, lock gates, lock values, electrical system, etc.

6. One wall of a U-frame gate monolith was used by Mr. Bullock to provide onsite training on the use of the system. He pointed out each type of deficiency and how to use the form provided to arrive at the deduct value for the deficiency and the rating for the wall. He was available to discuss the system and to answer questions throughout the test. The two U-frame gate monoliths and four other U-frame monoliths were chosen for the test.

7. Each monolith was rated in two parts. For the purpose of the survey, an imaginary line was drawn down the center of the lock which divided each monolith into a north section (wall plus one-half of the floor) and a south section. An individual condition index number was obtained for each section. In arriving at a condition index number for the U-frame monolith, it was decided that the lowest of the two condition index numbers (north section or south section) should be used as the rating for the U-frame monolith.

8. Port Allen Lock was being dewatered at the time of the inspection, and the floor of the lock was accessible to the inspectors; however, there was still a great deal of water in the inlet and outlet filling system, and the inspectors were not able to inspect the filling and emptying system. The procedure used was to inspect the top and the exterior aboveground surface of the lock walls and then enter the dewatered lock chamber to inspect the interior walls and the floor of the chamber.

9. Upon completion of the inspection, each inspector calculated a condition index number for each section (north and south), and a comparison was made with the values obtained by the other inspectors. After discussion of the results and deficiencies found in the concrete of the lock, several changes were recommended to the condition index system. These changes were for the deduct values for deposits, leakage, corrosion stains, and missing armor and the addition of deficiency categories for "Spalling at Joints" and "Ruptured Waterstop." It was recommended that the system allow for the selection of a 5 or 10 deduct value for the deficiency categories of corrosion stains and damaged armor and that deduct values ranging from 5 to 20 be allowed for leakage and deposits, depending on the degree of seriousness of these deficiencies. If these recommendations had been implemented prior to the test at Port Allen Lock, the condition index numbers obtained by the inspectors for the U-frame monoliths would have been in much closer agreement. The same deficiencies were noted by all the inspectors, but some felt they were not serious enough to rate the deduct values given by the current system while others used the minimum deduct values allowed. All agreed that if the system had allowed a lower deduct value to be used they would have chosen the lower value.

10. A simplified inspection form was used in the Port Allen Lock test, and it made the inspection and calculation of the condition index much easier than the previous tests. A copy of the simplified inspection form is attached as enclosure 2.

11. A summary of the results obtained by the test participants is contained in Table 1 (enclosure 3).

Conclusions:

12. The proposed concrete condition index system can be used on a U-frame lock, and it provides consistent results that are representative of the condition of the concrete in the lock. Implementation of the recommendations made in paragraph 9 will provide a condition index value that is more representative of the condition of the concrete in the lock and will result in more consistent values obtained by different inspectors.

3 Encls

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LOCK ______________________ BLOCK NO __________

DATE ____________ BY ________________

ALIGNMENT PROBLEMS ______________________________

	DIVISION A				DIVISION B			
20 CRACK WIDTHS	≤.01	≤.04	≤.08	>.08	≤.01	≤.04	≤.08	>.08
24 HORIZ. CRK.	10	20	30	40	5	10	15	20
25 VERT. & TRANSV.	10	20	30	40	–	10	20	30
26 VERT. & LONGIT.	10	30	50	70				
27 DIAGONAL	20	40	60	80				
28 RANDOM	10	20	40	60				

VOLUMETRIC CRACKING	% WIDTH (A)		% DEPTH (A)	% WIDTH (B)		% DEPTH (B)
21 CHECKING	100%		10%	10%		100%
22 D-CRACKING		50			50	
23 PATTERN	100%		5%	5%		100%
30 VOLUME LOSS		25			25	
31 ABRASION	100%		2%	2%		100%
32 CAVITATION		10			10	
33 HONEYCOMB	50%		5%	5%		50%
34 POP-OUTS		10			10	
35 SCALING	20%		5%	5%		20%
36 SPALLING		5			5	
37 DISINTEGR.	OTHER:			OTHER:		

40 STEEL	ANY AREA		> 50% AREA
42 REINFORCING	30		60
43 PRESTRESS	60		
CONDUITS	≤3"	≤6"	>6"
31 ABRASION	10	20	30
32 CAVITATION	20	40	60

MAX. DIV. A____

MAX. DIV. B._____

	DIVISION C	
41 CORROSION STAINS	10	
44 DAMAGED ARMOR	10	
50	MODERATE	HEAVY
51 LEAKAGE	10	20
52 DEPOSITS	10	20

SUM DIV. C___

DIVISION D

	DECK AREA	
CAT.	<25%	>25%
	5	10

SUM DIV. D__

SUM A+B+C+D = ________

C.I. _____

LOCK BLOCK INSPECTION FORM
FIGURE 2

Enclosure 2

Table 1

Port Allen Lock

U-frame Monolith Ratings

Name of Inspector	Gate #2 Monolith		#3 Monolith		#14 Monolith		#23 Monolith		#24 Monolith		Gate #4 Monolith	
	North	South	North	South	North	South	North	South	North	South	North	South
Bill McCleese	75	75	70	80	75	80	70	80	65	75	70	80
Tony Kao	80	80	70	80	70	70	80	85	70	75	70	75
Rupert Bullock	75	75	70	70	75	80	70	80	65	75	80	80
Terry Cox	75	85	90	90	90	80	80	90	65	85	80	80
Mel Stegall	75	75	80	80	80	80	75	80	70	75	80	80
Buddy Boren	80	90	65	80	75	80	75	80	70	80	80	90
Bob Grubb	75	85	70	70	70	70	80	70	65	75	80	80
Rueben Mabry	80	80	70	80	75	80	80	80	60	80	80	80
Mike Bourgois	85	85	75	75	85	75	85	75	55	75	85	75
Jose Lizarribar	80	80	60	70	80	80	80	80	70	80	80	80
Average	78.0		72.0		75.5		75.5		65.5		77.5	
Std Deviation	3.32		7.81		3.5		4.15		4.72		4.03	

NOTE: Each U-frame monolith was rated in two parts, the north half and the south half. The condition index number for the U-frame monolith was taken as the lowest of the rates for the two parts. These numbers are circled in the above table and were used to determine the average and the standard deviation.

CEWES-SC-A 15 July 1987

MEMORANDUM FOR RECORD

SUBJECT: Trip Report - Dashields Locks & Dam to Evaluate a Concrete Condition Index System for Locks

Background:

1. Part of the effort under the Operations Management Problem Area of the REMR Research Program is to develop condition index systems for the US Army Engineer Waterways Experiment Station (WES) civil works structures. A Concrete Lock Wall Condition Index System has been developed by Mr. Rupert Bullock under contract to WES. The system was field tested at Lock & Dam No. 20, Upper Mississippi River in December 1986. The results were very promising, but it was the opinion of those who participated in the test that additional tests at different locks with different types of deficiencies should be conducted before the system is proposed for adoption. Suggestions included a high lift lock, a dewatered lock, a lock in the Ohio River Division (ORD) and a lock in the South.

2. ORD personnel suggested that Dashields Locks be used for the test in ORD.

Objective:

3. The objective was to evaluate the condition index system for rating the concrete in the lock walls at Dashields. Factors to be considered in the evaluation were the following:

a. Does the system produce consistent results, and is it independent of the inspector using the system?

b. Does it account for all the types of deficiencies possible in the concrete of a navigation lock?

c. Are the types of deficiencies properly weighted so that the more serious deficiencies result in a lower condition index number?

d. Is the system easy to use, and will it be accepted by field personnel?

4. A secondary objective was to provide Pittsburgh District personnel training on the use of the system.

Evaluation:

5. Dashields Locks & Dam was visited on 8-9 July 1987 (a list of participants is provided as enclosure 1). The morning of the first day was devoted to reviewing the proposed condition index system and selecting lock wall monoliths for the test. The review session was to acquaint the participants with the system and the logic used in its development. Mr. Rupert Bullock led the discussion and explained how the rating system was envisioned to work. There

was some general discussion on how many monoliths of a lock needed to be evaluated to arrive at a condition index rating for the lock. The concern was that the inspector would generally pick a few monoliths in the worst condition and use these values for the overall rating of the lock. It was suggested that the overall rating of a lock be given by two numbers: the lowest value obtained from any of the monoliths and an average value obtained from averaging the condition index of the gate monoliths and 10 percent of the other monoliths which are in the worst condition. Inspectors should rate all monoliths which contain any serious deficiencies but should use only the rating from the gate monoliths and 10 percent of the other monoliths for the overall rating of the lock.

6. A gate monolith and one other were used by Mr. Bullock to provide on-site training on the use of the system. He performed the rating on these blocks, pointing out each type of deficiency and how to arrive at the deduct value for each deficiency. Only the top surfaces of the monoliths were rated the first day. After this on-site training, five other gate monoliths and five interior lock monoliths were rated by the participants.

7. A work barge was provided on the second day for access to the vertical walls of the lock for assessing their condition. The lock was resurfaced with concrete sometime ago and has been patched numerous times since. This condition made it extremely difficult to determine if the cracks on the surface were just cracks in the overlay and patches or if they extended into the base concrete. All vertical surfaces, including all openings in the top of the lock walls, were examined very closely to see whether cracks in the overlay extended down the vertical surfaces beyond the depths of the overlay. If they extended beyond the overlay, they were considered structural cracks and reported accordingly. If the cracks did not extend beyond the overlay, they were considered part of the general surface deterioration and reported accordingly. The interpretation of these cracks was the greatest cause of discrepancies in the condition index numbers obtained for the same monoliths by different inspectors.

8. Upon completion of the inspection, each inspector calculated a condition index number for each monolith evaluated, and a comparison was made with the values obtained by other inspectors. There were a few instances in which large discrepancies were found to exist because of calculation errors. These errors occurred because the inspectors did not fully understand the calculation procedure and pointed out the need for adequate training before the system is implemented. The possibility that a computer program could be written which would take the data obtained from the inspection and do all the necessary calculations to obtain the condition index number was discussed and will be pursued. The desirability to simplify the inspection forms was also discovered, and forms more suitable for providing data for the computer program will be developed.

9. Large differences in the condition index number obtained for a monolith which were not the result of a calculation error were discussed in detail, and the monolith in question was revisited to look at the deficiencies again and to discuss the reason each inspector rated them as he did. In most cases the differences occurred because of the judgment made by the inspectors as to whether or not a crack extended beyond the concrete overlay or patch. The concrete overlay was badly deteriorated with numerous delaminations, which made it extremely difficult to determine by the use of visual inspection alone whether a crack extended into the base concrete. A more detailed inspection using coring and other nondestructive testing methods would have been very useful in this situation and would have resulted in closer agreement on the condition index numbers for the monoliths.

10. A summary of the results obtained by the test participants is contained in Table 1 (enclosure 2).

Conclusions:

11. The rating of a lock that has a concrete overlay is extremely difficult when based on visual inspection alone. This difficulty may result in large variations of the condition index number obtained by different inspectors for lock monoliths using the proposed system. This variation is not the fault of the system, and, in such cases, visual inspection should be supplemented by other nondestructive testing methods to minimize uncertainties concerning deficiencies in the concrete.

12. A computer program for calculating the condition index numbers for lock monoliths based on data from the inspector would be helpful and might help to minimize errors. Also some simplification of the forms used to note deficiencies in the concrete is desirable.

2 Encls

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DASHIELDS LOCKS AND DAM

Lock Monoliths Ratings

Name	L-19	L-21	L-33	L-35 Gate	M-5 Gate	M-9	M-10 Gate	M-17	M-21 Gate	M-24 Gate
Bill McCleese	20	75	50	50	50	60	70	70	50	50
Rupert Bullock	40	70	60	60	65	60	65	80	55	55
Tony Kao	40	85	70	40	60	50	60	70	60	60
Terry Shilley	40	75	60	55	60	60	80	60	60	60
Bob Waigand	20	75	50	30*	50	60	60	70	55	65
John Menniti	20	65	60	40	55	60	65	70	65	60
Al Remaly	25	75	50	60	50	60	70	70	50	55
Average	29	74	57	48	5	59	67	70	56	58
Std. Deviation	9.4	5.6	7	10.6	7.5	3.5	6.5	5.3	5.2	4.5

* This value is derived from a possible transverse crack in the monolith. The crack definitely exists in the overlay, but the other inspectors believed it to be confined in the overlay and did not rate it as a major deficiency.

CEWES-SC-A 25 March 1988
Revised

MEMORANDUM FOR RECORD

SUBJECT: Trip Report to John Day Lock to Evaluate a Concrete Condition Index System for Locks

Background:

1. A concrete lock wall condition index system has been developed and field tested at two low-lift gravity locks and a U-Frame lock. The purpose of this trip was to test the system at a high-lift lock and make any adjustments or modifications deemed necessary. North Pacific Division (NPD) personnel were contacted earlier concerning a site for the field test. John Day Lock was selected since it has experienced more problems than the other high-lift locks at NPD. Some major repairs have been made at the lock, and this inspection allowed us the opportunity to examine how the repairs were holding up and how the condition index system accommodated these repairs.

2. John Day Lock is a high-lift lock located on the Columbia River about 120 miles upstream from Portland, OR. The lock chamber is 86 ft wide by 650 ft long and is one of the highest single-lift locks in the world with a maximum lift of 113 ft. The gates at the lock are unusual in that the upstream gate is a submersible lift gate and the downstream gate is a vertical lift gate.

Objective:

3. The objective was to evaluate the condition index system for rating the concrete in the lock walls at John Day Lock and to obtain field input on the system. Factors to be considered in the evaluation were the following.

a. Does the system produce consistent results, and are results independent of the inspector using the system?

b. Does it account for all the types of deficiencies possible in the concrete of a high-lift gravity lock?

c. Are the types of deficiencies properly weighted so that the more serious deficiencies result in a lower condition index number?

d. Does the system properly handle deficiencies that have been repaired?

4. A secondary objective was to provide training to personnel of NPD on the use of the system and to obtain their input for improvements to the system.

Evaluation:

5. The evaluation took place on 21-23 March 1988 (list of participants is provided as enclosure 1). The first meeting took place on the afternoon of

21 March at the Division office. Participants had been provided a copy of the report describing the condition index system earlier, and this meeting was to provide a brief overview of the system and to answer any questions anyone might have before visiting the lock. Mr. Rupert Bullock discussed the logic behind the system and went through several examples for rating lock monoliths.

6. John Day Lock was visited on the 22 March 1988. The lock was dewatered, which allowed us to get down into the lock chamber and the filling and emptying system to inspect repairs that had been made and to look for any new deficiencies. As mentioned earlier, John Day Lock is about 120 miles from Portland. The participants traveled to and from the lock and conducted the test all in 1 day. Although this amount of time was sufficient for the purpose of this evaluation, it would not have provided enough time for a detailed condition index of the lock by an inspector.

7. Upon arriving at the site, a set of drawings made from a previous condition survey showing deficiencies was used to select the monoliths to be used for evaluation. All four gate monoliths and five lock chamber monoliths were chosen. Each inspector was then given a set of forms to use in the evaluation. Mr. Bullock was available to answer questions at all times and also participated in the evaluation.

8. Each of the selected monoliths was inspected from the top and from inside and outside the lock chamber. The monoliths on the riverside were also inspected from the filling and emptying conduit. Upon completion of the inspection, each inspector calculated a condition index number for each of the selected monoliths.

9. A meeting was held at the Division office on the morning of 23 March to compare the ratings obtained by the participants and to discuss the reasons for any large differences. A table showing the condition index numbers obtained by each inspector is attached (Table 1). The range of the condition index numbers obtained for several of the monoliths was larger than those obtained during the other field tests. A review of the ratings obtained by each inspector revealed some of the reasons for the scatter in the condition index numbers. The single largest contributor was differences in the width of cracks obtained by the inspectors. The short time available at the lock prevented a detailed inspection and measurement of crack widths. Most participants stated that they had guessed at the crack widths since they were unable to take a measurement at the location where they considered the crack to be the widest. Another reason for the scatter was a lack of information available at the site on previous repairs made at the lock. Details on the extent and location of posttensioning tendons were not available, and some inspectors considered cracks to be repaired while others listed them as a deficiency. The condition index values obtained for each monolith were reviewed and are discussed below:

Monolith 29G - Condition index numbers for this monolith ranged from 60 to 95. The differences were the results of a longitudinal crack in the monolith that one inspector considered completely repaired while others were not sure of the extent of the posttensioning and thus considered the crack as a deficiency. Also evidence of leakage when the lock is in operation was included in the evaluations of some inspectors.

Monolith 23 - Index numbers ranged from 70 to 90. The low values were attributed to leakage that occurs when the lock is in operation, and only a few of the inspectors were aware of this deficiency. This discrepancy would be eliminated by the inspection of the lock under operating conditions.

Monolith 17 - Index numbers ranged from 65 to 90. The low value was attributed to the spalled condition that exists at a diagonal crack from the lock chamber to the filling and emptying system conduit. The crack has been grouted and posttensioned and appears to be totally repaired. The spall was not repaired because it was considered to be on the side of the lock chamber that receives no loading during operation of the lock. For these reasons, most inspectors did not deduct for the spall. The one who did deduct for the spall obtained the low index number for this monolith.

Monolith 9 - Close agreement was obtained for the condition of this monolith.

Monolith 5G - The differences in the index values obtained for this monolith (60 to 95) were caused by a different interpretation of a crack on the deck. Some considered the crack to be a surface crack, and others considered it to be a vertical and longitudinal crack (a better place to observe and measure the crack would have been below the deck, but time for this was not available).

Monolith 30G - This monolith had the highest standard deviation for index numbers of all the monoliths rated. The index numbers ranged from 40 to 85, and the reasons for the differences were the same as explained above for monolith 5G.

Monolith 22 - There was agreement on the deficiencies of this monolith. A difference of opinion on the crack width and the amount of leakage through the crack during operation was the reason for the difference in index numbers. An opportunity to thoroughly inspect the crack and take measurements would have resulted in a closer agreement on the monolith's index number.

Monolith 6G - Index numbers ranged from 60 to 95. There were several vertical and longitudinal cracks in the top of the monolith. Some inspectors considered these to be very shallow and counted them as deck cracking, which resulted in a high index number for the monolith. Others considered them to be true vertical and longitudinal cracks, which resulted in a lower index

number. If time had permitted, an inspection of the gallery below the deck would have cleared up this discrepancy.

10. During the discussion of the results obtained from the field test, several items were raised for consideration in preparing the final report on the condition index system. These items are summarized as follows:

a. A lock should be rated based on surveys conducted while the lock is in operation (to gather information on leakage) and while in an unwatered condition to inspect the chamber and the filling and emptying system.

b. Subsequent surveys should be conducted at the same time of year to avoid differences in crack widths caused by ambient temperature differences.

c. Consideration should be given as to whether a larger deduct should be considered for multiple cracks as opposed to the current method of the deduct value based entirely on the width of the largest crack.

d. The report should state that details on previous repairs made at the lock should be obtained by the inspector before the survey is made. This is particularly true where the repair involved posttensioning.

e. Consideration should be given to using a formula for obtaining deduct values for crack widths. This method would prevent the large jump in the deduct value from one crack-width category to the next category.

f. For volume loss deficiencies, the original width of the lock wall at the elevation of the deficiency should be taken as the cumulative width of the concrete portions of the lock wall at that elevation. For example, if the total width of the lock wall at elevation 200 is 30-feet and a 10-foot-diam conduit runs through the lock wall along elevation 200, the width of the concrete wall should be taken as 30 feet minus 10 feet or 20 feet. This determination of volume loss deficiencies should be made clear in the report.

g. Sketches with the deficiencies being considered should be included in the report to accompany the examples in Appendix B.

h. More room should be provided on the inspection form to allow for remarks, sketches, etc.

i. Some provisions should be made for an on-site training session for all inspectors who will use this system.

Conclusions:

11. The condition index system tested can be used successfully on a high-lift lock. Adequate time is needed for a detailed survey to actually measure crack

widths and to determine the true extent of the cracks. It is essential that the inspector obtain information on the extent and exact location of previous repairs made at the lock before he begins his survey. Detailed drawings showing the exact location of posttensioning should be available during the survey.

2 Encls

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Concrete Lock Wall Condition Index System

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Table 1

John Day Lock

Condition Index of Lock Monoliths

Inspector	Monolith Number ("G" means gate monolith)									Lock Index	
	29G	23	17	9	5G	30G	22	16	6G	Ave	Low
David Ross	95	75	80	85	95	85	80	60	95	83	60
Ed Daugherty	70	80	85	90	90	75	90	60	70	79	60
Dennis Hopman	65	70	80	90	NR	55	70	50	NR	69	50
Seichi Konno	70	80	85	80	90	70	80	70	80	78	70
Martin McCann	60	90	80	90	95	55	80	55	95	78	55
Louis Boitano	70	80	90	90	90	45	80	50	90	76	45
Rupert Bullock	80	85	65	80	60	40	75	60	60	67	40
Carolyn Flaherty	70	80	90	NR	85	55	75	60	90	76	55
Jerry Maurseth	70	80	90	90	NR	55	80	50	NR	74	50
Average	72	80	83	87	86	59	79	57	83		
Std. Deviation	9.46	5.27	7.48	4.29	11.26	13.64	5.15	6.29	12.50		

NR = Not Rated